SEA-AR/BLM COOPERATIVE STUDIES

REYNOLDS CREEK WATERSHED

Northwest Watershed Research Center
Western Region
Agricultural Research
Science and Education Administration
U. S. Department of Agriculture

INTERIM REPORT NO. 11

Cooperative Agreement No. 12-14-5001-6028

For Period January 1, 1980 to December 31, 1980

TO

Denver Service Center
Bureau of Land Management
U. S. Department of Interior
Denver, Colorado

FEBRUARY 1981

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NOTE: Generally, a variety of watershed data are compiled on a calendar year basis. However, the water year, beginning October 1 and ending September 30, has proven best for hydrologic comparisons.

INTRODUCTION

Cooperative watershed research between the Science and Education Administration-Agricultural Research, U. S. Department of Agriculture, and the Bureau of Land Management, U. S. Department of Interior, was initiated in 1968 under Cooperative Agreement No. 14-11-0001-4162(N). Also, the Memorandum of Understanding, dated July 6, 1960, which is part of the Cooperative Agreement, specifies the overall responsibility of each agency.

This interim report summarizes progress and results on the Reynolds Creek Watershed and supporting studies on the Boise Front from October 1 through September 30, 1980. Data collection, processing, analyses, and reporting are according to the FY 1980 work plan. Progress reports are given by the individual sections of the work plan. A copy of the FY 1980 work plan precedes the progress reports.

Supporting information and data are presented in Northwest Watershed Research Center Annual Reports for 1972 and prior years and in Interim Reports No. 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 for the AR-BLM studies in the Reynolds Creek Watershed under Cooperative Agreement No. 12-14-5001-6028.

Additions to the Staff during the past year have greatly expanded our capability to conduct research for soil-water-vegetation management on rangeland watersheds. Dr. Keith Cooley, Hydrologist; Dr. A. Leon Huber, Hydrologist; and Dr. J. Ross Wight, Range Scientist, joined the staff in 1980.

Dr. Wight is coordinating a SEA-AR project on Rangeland Resource Modeling. This effort will provide significant input to BLM rangeland resource management needs.

Dr. Cooley is providing SEA-AR hydrologic input to the Saval Ranch project. He will be coordinating studies on applying Reynolds Creek hydrologic data to model development and testing their applicability to the Saval project.

Dr. Huber's major research responsibilities are in the snow hydrology area. However, he will have a significant input to our hydrologic modeling and water quality modeling activities.

In cooperation with the Chipmunk Grazing Association, BLM and Eli Lilly Company treated one of the Reynolds Creek watersheds with "GRASLAN" (Tebuthiuron) for sagebrush control. Soil and water samples are being tested periodically for chemical residues. Vegetation in treated and untreated areas will be monitored.

Introduction Figures 1 and 2 locate major experimental sites on Reynolds Creek (Figure 1) and the Boise Front (Figure 2).

Additional copies of this report or further information on reported work can be obtained from:

Northwest Watershed Research Center
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1175 South Orchard, Suite 116
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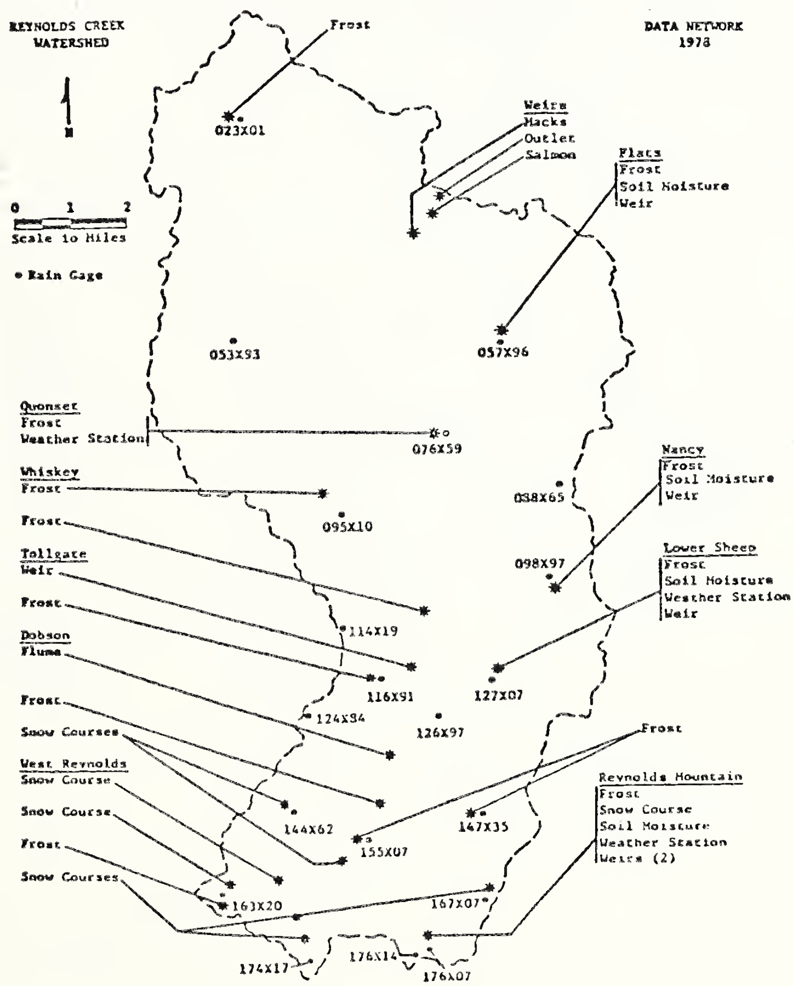

Figure 1.--Reynolds Creek Watershed

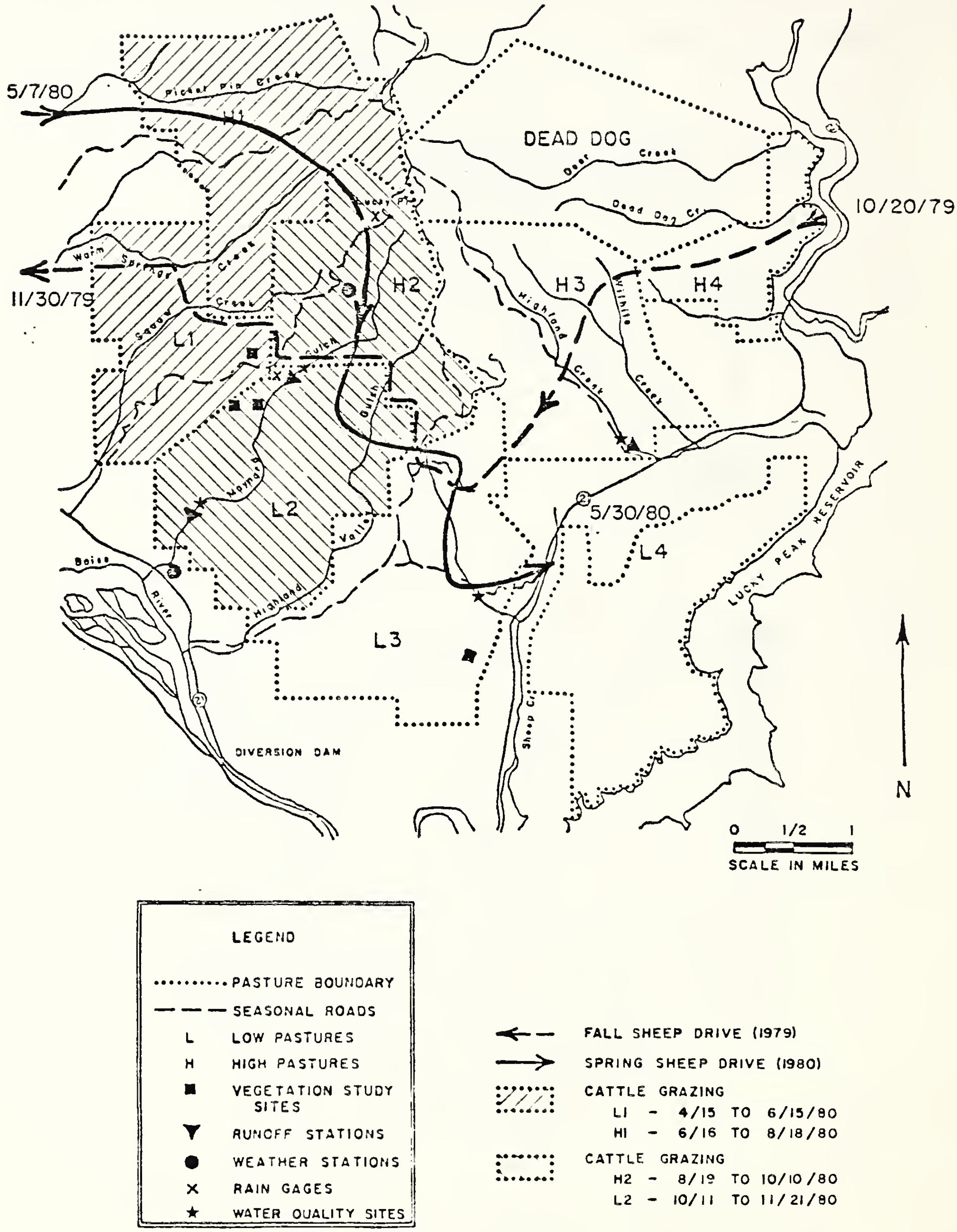

Figure 2.--Boise Front.

STAFF

NAME	TITLE	SERVICE DATES*
Aaron, Virginia M.	Hydrologic Technician	
Belknap, Stephen P.	University of Idaho Cooperator-Irregular Employee	11/17/80-Present
Brakensiek, Donald L.	Research Hydraulic Engineer (LL & RL)	
Burgess, Michael D.	Electronic Technician	
Butler, Donna M.	Administrative Officer	
Campbell, Michael D.	Hydrologic Aid (Perm., 32 Hr/Wk)	1/15/79-12/27/80
Cooley, Keith R.	Hydrologist	1/27/80-Present
Coon, Delbert L.	Hydrologic Technician	
Critchlow, Diane M.	Clerk Typist (Perm., 32 Hr/Wk)	11/18/79-7/9/80
Engleman, Roger L.	Mathematician	
Griffith, Suzann C.	Clerk Typist (Perm., 32 Hr/Wk)	11/2/80-Present
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Harris, James H.	University of Idaho Cooperator-Scientific Aid III	
Hennefer, Shari L.	Clerk Typist	
Hoagland, Jerry	University of Idaho Cooperator-Irregular Employee	
Hoagland, Roy M.	Automotive Mechanic	
Huber, A. Leon	Hydrologist	6/1/80-Present
Johnson, Clifton W.	Research Hydraulic Engineer	
Kroeger, Shirley C.	University of Idaho Cooperator-Research Technician	4/15/79-12/31/80
Miller, Cindy	Boise State University Cooperator-Technician	11/3/80-Present
Morris, Ronald P.	Hydrologic Technician	
Mosby, John D.	Boise State University Cooperator-Technician	11/17/80-Present
O'Brien, Rebecca L.	Hydrologic Aid (Temp., 180-Day Appt.)	11/18/79-8/18/80
Perkins, Lee	Machinist	Retired 9/11/80
Robertson, David C.	Hydrologic Technician	
Royston, Janice L.	Boise State University Cooperator-Technician	5/17/80-Present
Rychert, Robert C.	Boise State University Cooperator-Professor of Microbiology	5/19/80-8/14/80
Sherman, David D.	Boise State University Cooperator-Technician	11/10/80-Present
Smith, Jeffrey P.	Hydrologist	
Stephenson, Gordon R.	Geologist	
Trautman, Kenneth W.	Engineering Equipment Operator	
Viegel, Anne P.	Boise State University Cooperator-Technician	8/17/80-Present
Wight, J. Ross	Range Scientist	6/29/80-Present
Wilson, Glenna A.	Purchasing Agent	

*If other than whole year.

BLM-SEA ANNUAL WORK PLAN FOR FY 1980

INTRODUCTION: The following work plan items contribute to the objectives of Paragraph III of the Bureau of Land Management Interagency Agreement No. YA-515-IA8-21 dated September 19, 1978. Certain items in the work plan represent a continuation and/or completion of work from previous years. In some cases, the continuation represents collection of hydrologic data or watershed resource inventories. This is required for sampling the influence of climatic variability on hydrologic factors and cumulative effects of rangeland management practices. USDA-SEA watershed management research, not a part of this work plan, in many instances supplements and/or complements the following work plan items:

1. PRECIPITATION

   Continue development of a stochastic model for precipitation events occurring on the Reynolds Creek Watershed. Commence the application of the monthly and annual models to comparable rangeland areas in Idaho, Oregon, and Nevada. Precipitation network operation on the Reynolds Creek and satellite watersheds will be upgraded with electric clocks.

2. VEGETATION

   Two existing soil water balance models will be tested with Reynolds Creek soil moisture data to verify their adequacy for predicting soil water depletion. Investigations will commence on predicting soil moisture stress and utilizing it as an input to forage yield modeling. Continued research on the Boise Front rest-rotation system will include surveys on species composition and cover and seedling establishment and survival at four grazed and four non-grazed sites. Bitterbrush utilization surveys will determine use by deer and/or cattle.

3. RUNOFF

   Determine streamflow volume, duration, and rate characteristics of rangeland watersheds in southern Idaho, northern Nevada, and eastern Oregon, using (1) watershed characteristics and climatic factors, and (2) probability analysis methods. Results will be prepared for publication.

   An analysis utilizing soil water characteristic data for predicting Green-Ampt infiltration equation parameters will be completed. A study on modifying the SCS runoff equation with the Green-Ampt infiltration equation will be initiated.

   Geologic and groundwater data and information collected on Reynolds Creek Watershed will be used to study the potentials for stock water and to investigate optimum procedures for developing it. The reporting of this effort can be utilized by BLM in similar areas to facilitate investigations of upland water sources for livestock and/or wildlife.

Continue runoff data collection at two main stem, three tributary and three source watersheds on Reynolds Creek and at two sites on the Boise Front study areas.

4. EROSION AND SEDIMENT

Study the effectiveness of range-fire suppression, seeding, grazing control, road closures, and wildlife habitat improvements on Boise Front Watersheds on controlling erosion and sediment yield. Results will be presented at the ASCE Watershed Management Symposium, July 21-23, 1980, and published in the proceedings.

Sediment sampling instrumentation at the two major stations on Reynolds Creek wiil be replaced to improve the reliability and accuracy of sampling. Continued data collection at four Reynolds Creek sites and two on the Boise Front will be reported in the FY 1980 annual report.

A procedure for predicting cover during the grazing season, based on antecedent precipitation, expected grazing season precipitation, and residual cover will be investigated and reported.

5. WATER QUALITY

Continue water quality observations on the Boise Front rest-rotation system for depicting sources and variations in water quality indicators due to both cattle and deer. Data from this management practice will be compared with similar types of data collected on deferred and open grazing systems on the Reynolds Creek Watershed.

PROGRESS REPORTS

1. PRECIPITATION

Personnel Involved

C. L. Hanson, Agricultural Engineer	Supervises the planning and design of precipitation studies; performs analyses and summarizes results.
K. R. Cooley, Hydrologist	Coordinates SEA-AR hydrologic research at the Saval Ranch, Nevada Research Project.
V. M. Aaron, Hydrologic Technician	Responsible for data reduction and processing.
D. L. Coon, R. P. Morris, and D. C. Robertson, Hydrologic Technicians	Responsible for data collection, compilation, and assist with analyses.
R. L. Engleman, Mathematician	Responsible for data compilation and assists in analyses.
M. D. Campbell, Hydrologic Aid	Assists in data reduction and processing.
J. Royston Cooperator (BSU)	Assists in hydrologic data reduction.

Reynolds Creek (Reynolds Creek site locations are shown in Introduction, Figure 1).

Development of a data set to use for modeling precipitation by events was continued. When this effort is completed next fiscal year, a continuous record from 12 precipitation sites on Reynolds Creek Watershed will be available for analysis.

STOCHASTIC GENERATION OF ANNUAL AND MONTHLY PRECIPITATION ON REYNOLDS CREEK WATERSHED

Average annual and monthly precipitation amounts and their variations are basic to many watershed hydrologic and natural resource studies. This need for precipitation information has become apparent in recent years to action agencies, such as the Bureau of Land Management, USDI, and consulting hydrologists for developing Environmental Statements for Public Lands. Most of the raingages are located in mountain valleys and, thus, do not represent the mean precipitation that falls on an entire watershed, which necessitates a procedure for estimating watershed precipitation as related to elevation.

The procedures that follow can be used to estimate annual and monthly precipiation. The procedures will provide an estimate of the mean as well as the range of annual and monthly amounts that can be expected in mountainous watersheds located in southwest Idaho.

Description of study area and data base: The data for this study were collected from the raingage network on the Reynolds Creek Experimental Watershed in southwest Idaho (Figure 1.1). A detailed description of the raingage network can be found in Hamon (1971) and Hanson et al. (1980). Data from all 38 sites shown in Figure 1.1 were used to develop the monthly and annual precipitation to elevation relationships. The record from these sites varied from 11 to 18 years. The records from the 17 sites with 18-year records were used to compute the monthly and annual standard deviations. The average annual precipitation varied from about 250 mm at the low elevations, about 1180 m, to 1101 mm at site 163X20, elevation 2164 m. The major winter storms moved onto the watershed from the south and southwest, causing high precipitation amounts on the southwest region of the watershed, and less precipitation on the northeast regions.

The data in Table 1.1 shows that 41 percent of the average annual precipitation fell from May through October at the lower elevation site 076X59; whereas, only 24 percent fell during the same period at the high elevation site 163X20. Monthly and annual precipitation at the four sites showed that July had the least average precipitation, ranging from 7 mm at 076X59 to 16 mm at 163X20. The greatest average monthly precipitation was during January, and varied from 38 mm at 076X59 to 204 mm at 163X20. In general, July, August, and September were the driest months and November, December, and January were the wettest. The data for the four sites with 18-year records are shown in Table 1.1, because these sites represent the change of precipitation with elevation changes, and the data from these sites will be used later for model evaluation.

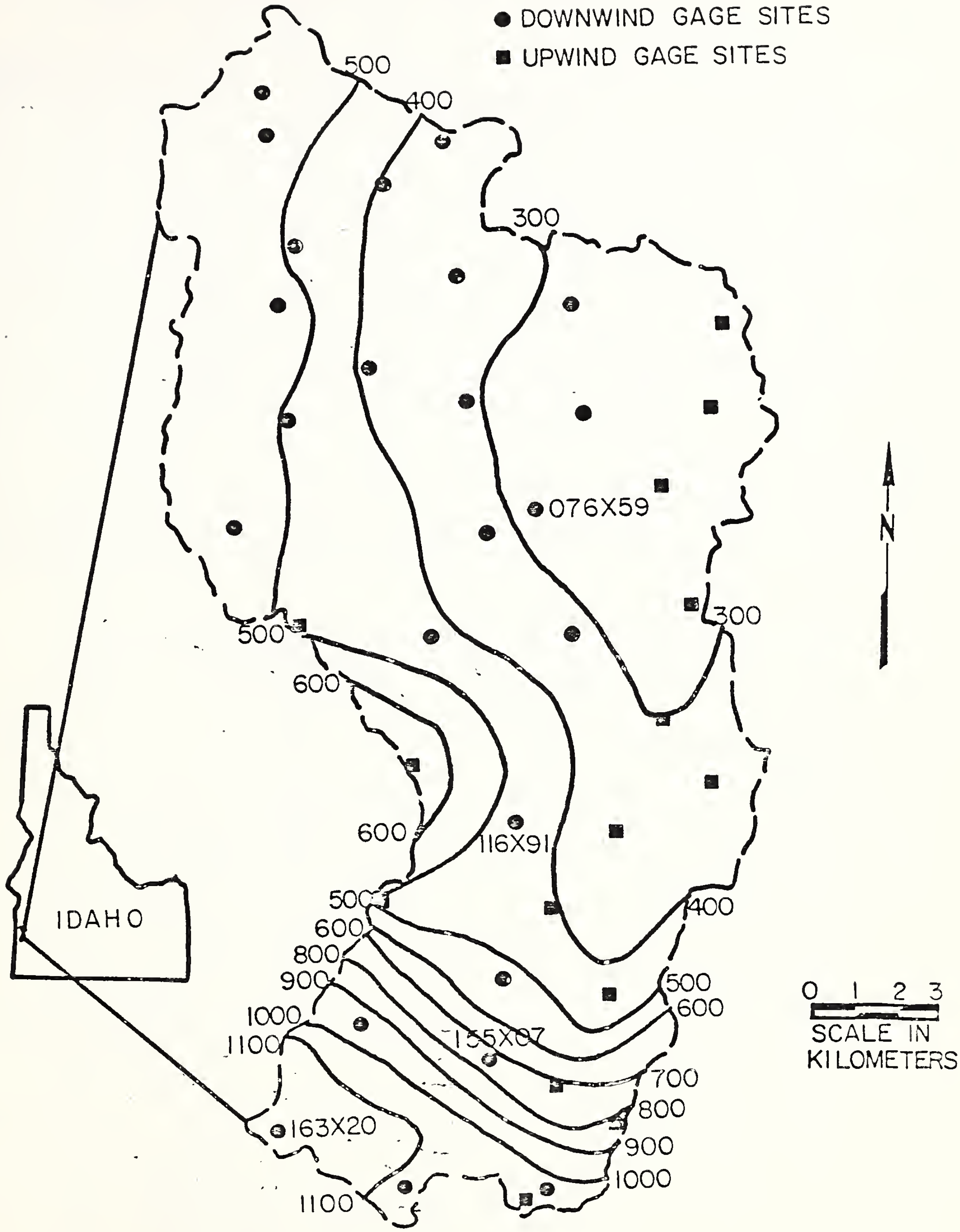

Figure 1.1.--Isohyetal map with the locations of the precipitation measuring sites, Reynolds Creek Experimental Watershed. Numbers indicate millimeters of annual precipitation.

Table 1.1.--Average monthly and annual precipitation at four sites with 18-year records and the U.S. Weather Bureau site at Boise.

Site	Months (mm) Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual (mm)
076X59 (1193 m)	38	20	23	25	18	34	7	20	12	22	30	30	279
116X91 (1454 m)	68	40	42	46	30	40	10	19	18	37	54	59	463
155X07 (1649 m)	116	69	70	61	43	46	15	28	24	52	89	95	708
163X20 (2164 m)	204	119	115	102	60	58	16	31	30	65	144	157	1101
Boise (1940-79) (865 m)	38	29	27	30	29	25	6	9	13	21	34	34	295

Annual and Monthly Precipitation Generation Equations

Annual: Hanson et al. (1980) found that there was a linear relationship between annual (calendar year) precipitation and elevation. They also found that because most winter atmospheric water moved over the watershed from the west and southwest, there was more precipitation on the south and west side of the watershed than on the east and northeast side. This concept was somewhat changed in this paper by designating most of the gage sites on the west side of the watershed as downwind sites and the gage sites on the east side of the watershed as upwind sites (Figure 1.1). The gage sites were stratified this way because preliminary analyses indicated that the sites along the west ridge were measuring precipitation coming upslope onto the watershed from the south and west and, thus, were in the same precipitation group as the sites on the west side of the watershed. Regression analyses were used to develop the relationship between annual precipitation and elevation for both the downwind and upwind sites.

Markovic (1965) evaluated several statistical distributions and found that annual precipitation data was best fitted by the lognormal 2-parameter function (Chow, 1954, Chow, 1964, and Haan, 1977). The lognormal 2-parameter probability density function is:

$$p_x(x) = \frac{1}{x\sigma_{\ln x} \; (2\pi)^{1/2}} \exp\left[- \frac{(\ln x - u_{\ln x})^2}{2\,\sigma_{\ln x}^2} \right] \qquad x > 0 \qquad [1]$$

where,

x = annual precipitation

x = a random variable

$u_{\ln x}$ = mean of the $\log_e$ values

$\sigma_{\ln x}$ = standard deviation of the $\log_e$ values.

The equation adapted from Clarke (1973) for generating annual precipitation using the lognormal distribution is:

$$Y = \exp(u_{\ln x} + \sigma_{\ln x} y) \qquad [2]$$

where,

Y = generated annual precipitation values

$u_{\ln x}$ = the mean

$\sigma_{\ln x}$ = the standard deviation of the $\log_e$ values of the site where data are available

y = a pseudo-random normal deviate (N(0,1)).

Monthly: A linear relationship between annual monthly precipitation and elevation was developed for each month using regression analysis. The data was stratified by upwind and downwind gage sites, as was done in the annual precipitation analyses. The average monthly values used were for years with precipitation because the months of July, August, and September did not have precipitation every year.

Because the months of July, August, and September did not have precipitation each year, the percent of years without precipitation was calculated so that the number of dry monthly values could be generated. The generation scheme consists of determining if the month in question has a percent of years without precipitation and if it does, generate a value from a uniform distribution to determine if the specific year being generated is a dry year.

The monthly precipitation data were best represented by the cube-root-normal distribution (Howell, 1960; Kendall, 1960; and Stidd, 1953). The necessary parameters for the generation function for this distribution are obtained from a cube-root transformation. The normal distribution was then fitted to the transformed data. The normal probability density function is (Haan, 1977):

$$p_X(x) = \frac{1}{\sigma(2\pi)^{\frac{1}{2}}} \exp\left[-\frac{(x-u)^2}{2\sigma^2}\right] - \infty \leq x \leq + \infty \qquad [3]$$

where,

x = monthly precipitation

X = a random variable

σ = standard deviation.

The equation for generating monthly precipitation using the normal distribution is (Clarke, 1973):

$$Y = u + \sigma y \qquad [4]$$

where,

Y = generated cube-root of monthly precipitation

u = mean of the cube-root transformed values

σ = standard deviation of the transformed values

y = a pseudo-random normal deviate (N(0,1)).

The monthly values generated from Equation 4 are then cubed to obtain the generated monthly precipitation record.

Examples of both the annual and monthly generation schemes are shown later in this paper.

ANNUAL PRECIPITATION GENERATION

Annual precipitation-elevation relationship: The equations developed for the downwind and upwind gage sites were:

$$\text{Downwind} \quad Y = -737 + 0.849X (R^2=0.920) \quad [5]$$

$$\text{Upwind} \quad Y = -632 + 0.646X (R^2=0.855) \quad [6]$$

where,

Y = average annual precipitation (mm)

X = elevation (m).

These equations are also shown in Figure 1.2.

As can be seen from Figure 1.2, the high coefficients of determination (R^2) indicate that there was a good annual precipitation-elevation relationship for both the downwind and upwind gage sites. Equations 5 and 6 are the equations that will be used later in the examples.

The relationship between the untransformed average annual precipitation and standard deviation of the annual totals is shown in Figure 1.3. This good relationship shows that there is a linear relationship between annual precipitation and standard deviation. The annual totals from both the downwind and upwind gage sites were combined from the 18 longest record stations to compute the equation shown in Figure 1.3 because the relationship was the same for both sets of gage sites.

The mean annual precipitation ($u_{\ell nx}$) required in Equation 2 is the average of the $\log_e$ values, which is the geometric mean and not the $\log_e$ of the average annual totals. The two $\log_e$ values are very nearly the same, however, with the $\log_e$ of the annual average being 0.02 greater than the average of the $\log_e$ of the annual totals. Because this difference is constant between sites, all one has to do to compute $u_{\ell nx}$ is to find the average annual precipitation from Equations 5 or 6, take the $\log_e$ of that average and subtract 0.02 to obtain the desired value for $u_{\ell nx}$. The relationship between the $\log_e$ of the average annual to the average of the $\log_e$ values will be investigated more thoroughly in the study for Idaho and surrounding areas.

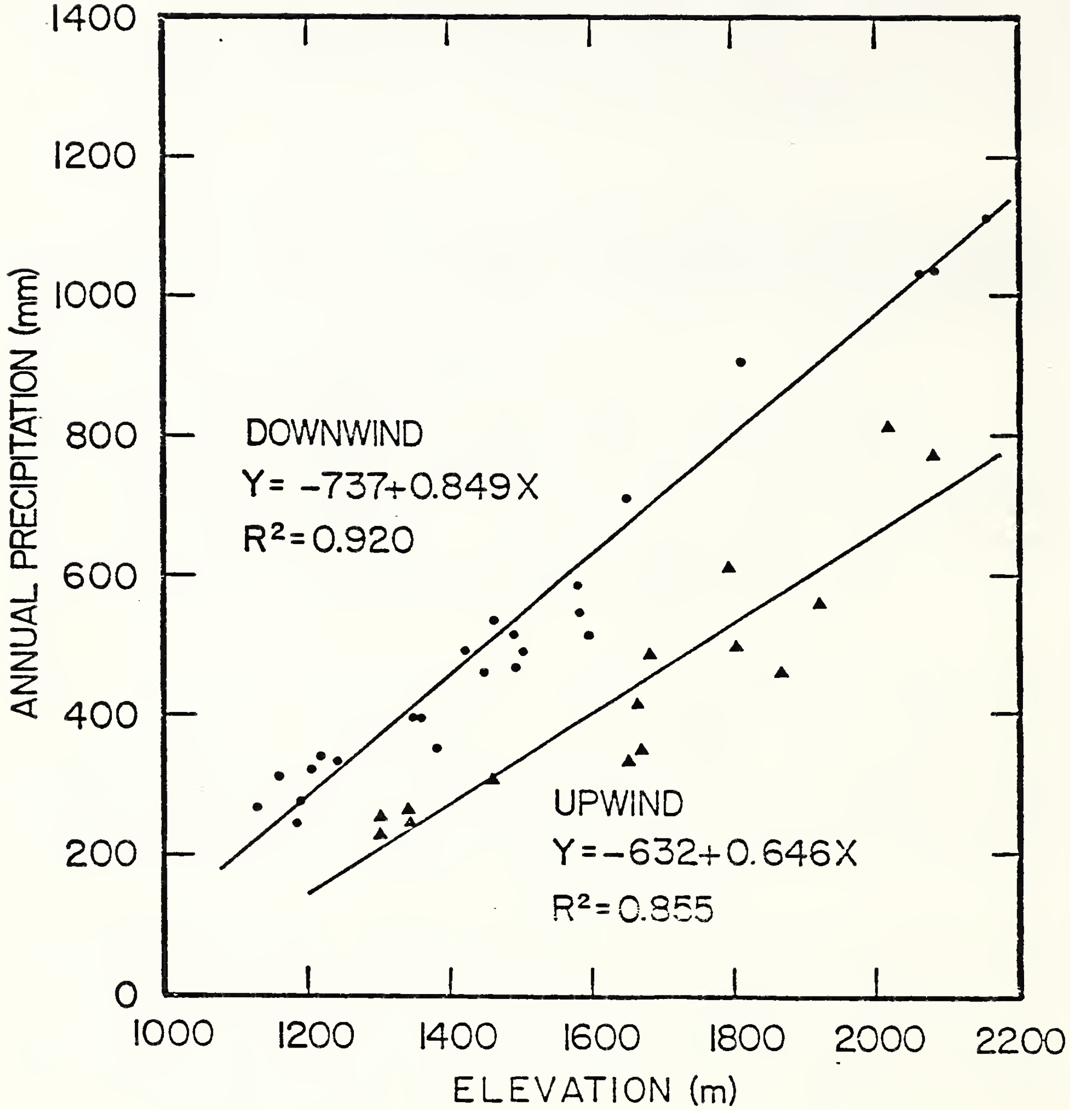

Figure 1.2.--Relationship between elevation and annual precipitation.

The second value required in Equation 2 is $\sigma_{\ell nx}$, which is a constant of 0.21 for the Reynolds Creek Watershed. This value of $\sigma_{\ell nx}$ appears to be very realistic even for the short record at Reynolds Creek Watershed, because the value was 0.20 for the 40-year record at the Boise Airport.

The third value required in Equation 2 is y. Values for y can be obtained from any table of pseudo-random normal deviates (N(0,1)) or computer facilities which have programs for generating these values.

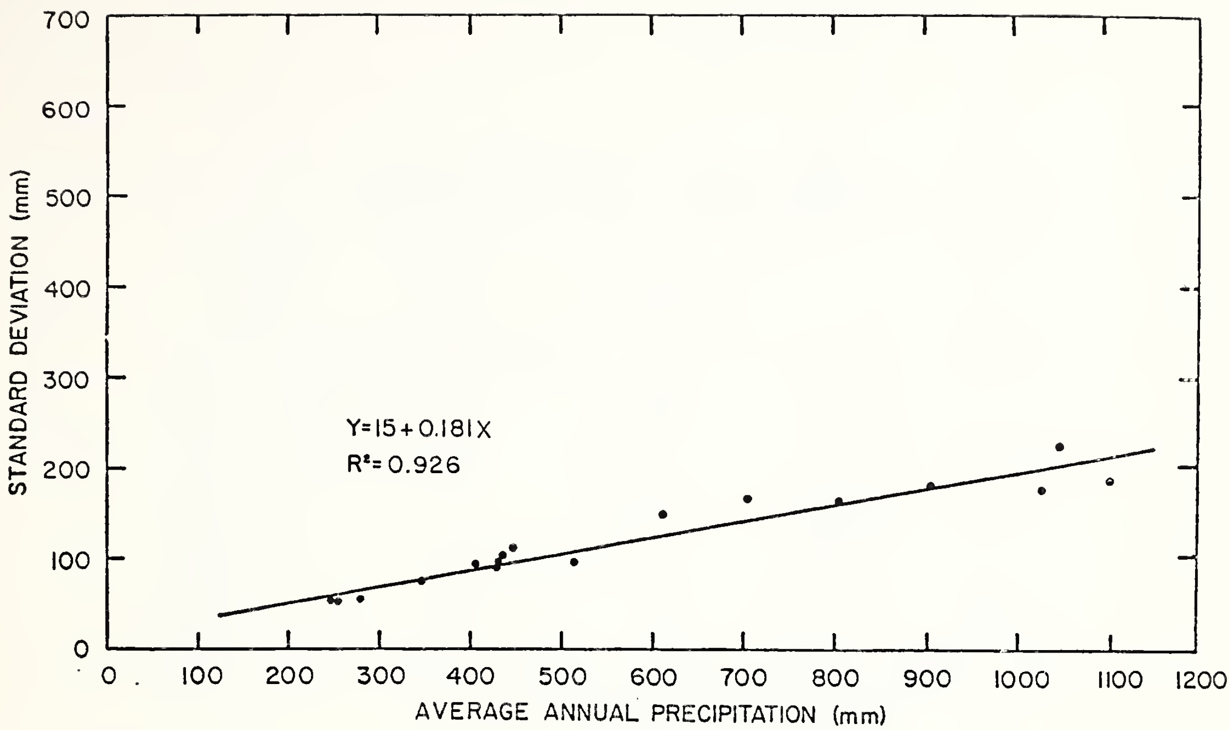

Figure 1.3.--Relationship between average annual precipitation and the standard deviation of the average annual precipitation.

A summary of 50-year simulations for four gage sites is presented in Table 1.2. The simulated annual average totals were within 3 percent of the measured values at the four gage sites. The simulated annual average was less at three of the sites than the measured and larger at one of the sites, indicating that the simulation was not consistently over or under estimating the average annual precipitation.

The simulated standard deviations were within 2 percent of the measured values at three of the sites and 16 percent less at site 116X91.

MONTHLY PRECIPITATION GENERATION

Elevation - precipitation relationships: Regression analysis was used to develop relationships between elevation and precipitation (Table 1.3). The relationships were developed, using the same downwind and upwind gage site stratification used in the annual precipitation analysis. As can be seen from Table 1.3 and Figure 1.4, separate equations were used to describe the elevation - precipitation relationship for each month except July and August, when one equation was used for both the downwind and upwind conditions. Separate equations are shown for each month in Table 1.3. Studies are being conducted at the present time to determine if any of the monthly equations can be combined.

Table 1.2.--A summary of 50-year simulations of average annual precipitation at four gage sites on Reynolds Creek Watershed.

		Average Precipitation (mm)	Standard Deviation (mm)	Range of Annual Totals (mm)
076X59	Measured	279	54	175 - 372
	Simulated	275	54	177 - 405
116X91	Measured	463	98	320 - 624
	Simulated	452	82	287 - 658
155X07	Measured	708	167	493 - 1044
	Simulated	729	170	415 - 1239
163X20	Measured	1101	188	828 - 1472
	Simulated	1068	192	747 - 1461

Table 1.3.--Regression coefficients used to compute monthly precipitation [Y = a + bX; Y = monthly precipitation (mm); X = elevation (m); a and b = coefficients].

	Downwind			Upwind		
	a	b	R^2	a	b	R^2
January	-157	0.164	.919	-120	0.111	.780
February	-113	0.106	.941	-133	0.105	.795
March	- 92	0.096	.956	- 81	0.074	.781
April	- 65	0.077	.968	- 43	0.050	.756
May	- 39	0.047	.902	- 38	0.040	.904
June	4	0.026	.796	7	0.020	.723
July	- 7	0.011	.745	- 7	0.011	.745
August	6	0.010	.548	6	0.010	.548
September	- 7	0.018	.762	- 6	0.014	.836
October	- 23	0.042	.893	- 31	0.040	.803
November	-133	0.119	.943	- 90	0.085	.848
December	-126	0.129	.948	-110	0.098	.834

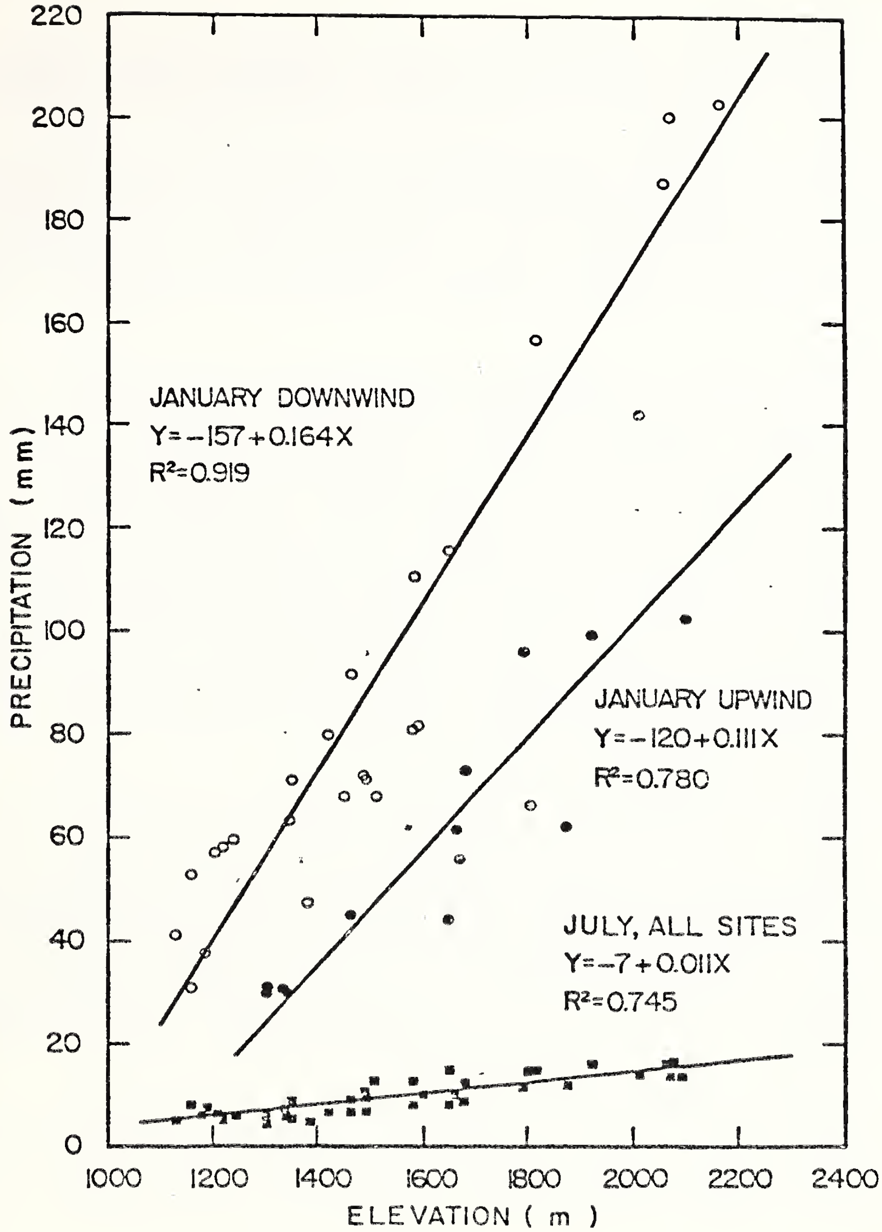

Figure 1.4.--Relationship between elevation and precipitation for January and July.

The equations in Table 1.3 would suggest that only two or three of the summer months can be combined because both the slope and intercept in the other monthly equations are quite different and, in general, follow a pattern throughout the year.

In general, the equations shown in Table 1.3 show that there is more monthly precipitation on the downwind (west) side of the watershed than on the upwind (east) side. The equations also show that there is more precipitation at the higher elevations during the winter than at the

lower elevations. During the summer, there was only a small monthly precipitation increase with increases in elevation (Figure 1.4).

The monthly value required in the simulation procedure is obtained by first determining if there is precipitation on the month in question, from the value of "A". Then if there is precipitation, use the appropriate equation shown in Table 1.3. This procedure will be shown in an example at the end of the section on precipitation.

Zero rain months: The monthly totals used for any month to obtain the means and standard deviation in Equation 3 are for months with precipitation. As can be seen in Tables 1.4 through 1.7, July, August, and September were the three months when no precipitation fell during some years. Coefficient A in Tables 1.4 through 1.7 is the percent of years when there was precipitation during the series of years. During the 18-year record from the Reynolds Creek Watershed, 4 years were dry during July and 2 years were dry during August and September. The values of A are about the same as those obtained from the 40-year record at the Boise WSO, except that there were 2 dry years during October, also, which was not the case for the 18-year Reynolds Creek Watershed record.

The simulated values of "A" shown in Tables 1.4 through 1.7, were generated by obtaining a uniform random number from either computer center procedure or a random numbers table. If the random number was larger than "A", there was no precipitation that year; and if the random number was equal to or smaller than "A", there was precipitation. The data in Tables 1.4 through 1.7 show that this procedure simulated the value of "A" very closely, except for August, at site 076X59, where the simulated value was 0.13 less than the measured value.

Table 1.4.—A summary of a 50-year simulation of monthly precipitation at gage site 076X59.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly (mm)	Measured	38	20	23	25	18	34	7	20	12	22	30	30
Average Monthly excluding years with no precipitation (mm)	Measured	38	20	23	25	18	34	10	22	13	22	30	30
	Simulated	35	17	23	20	18	38	8	14	12	24	28	29
Standard Deviation (mm)	Measured	30	12	17	21	13	20	7	27	11	19	16	28
	Simulated	25	8	16	16	15	26	7	15	8	19	16	24
Range (mm)	Measured High	102	43	65	80	44	77	26	101	40	73	60	132
	Low	8	6	3	7	3	7	0	0	0	1	4	2
	Simulated High	107	38	63	64	72	138	37	60	37	78	61	126
	Low	3	3	1	1	1	5	0	0	0	1	2	2
A (%)	Measured	1.00	1.00	1.00	1.00	1.00	1.00	.78	.89	.89	1.00	1.00	1.00
	Simulated	1.00	1.00	1.00	1.00	1.00	1.00	.78	.76	.92	1.00	1.00	1.00

Table 1.5.--A summary of a 50-year simulation of monthly precipitation at gage site 116X91.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly (mm)	Measured	68	40	42	46	30	40	10	19	18	37	53	59
Average Monthly excluding years with no precipitation (mm)	Measured	68	40	42	46	30	40	11	21	19	37	53	59
	Simulated	63	38	43	42	31	35	10	22	17	40	44	53
Standard Deviation (mm)	Measured	44	21	28	26	17	24	7	20	15	31	29	47
	Simulated	35	22	35	26	20	23	9	23	14	30	30	35
Range (mm)	Measured High	160	78	105	99	63	106	29	77	58	130	101	219
	Low	18	10	3	10	6	12	0	0	0	2	2	4
	Simulated High	162	132	200	133	105	101	43	99	62	137	128	161
	Low	9	13	3	5	4	1	0	0	0	1	8	1
A (%)	Measured	1.00	1.00	1.00	1.00	1.00	1.00	.89	.89	.94	1.00	1.00	1.00
	Simulated	1.00	1.00	1.00	1.00	1.00	1.00	.86	.82	.98	1.00	1.00	1.00

Table 1.6.--A summary of a 50-year simulation of monthly precipitation at gage site 155X07.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly (mm)	Measured	116	69	70	61	43	46	15	28	24	52	89	95
Average Monthly excluding years with no precipitation (mm)	Measured	116	69	70	61	43	46	17	31	25	52	89	95
	Simulated	125	65	78	57	49	54	17	32	24	41	78	96
Standard Deviation (mm)	Measured	72	34	44	31	22	29	13	25	18	42	54	71
	Simulated	75	32	40	32	29	34	13	25	19	29	50	71
Range (mm)	Measured High	267	125	157	124	86	110	47	106	71	181	179	311
	Low	27	17	17	8	10	11	0	0	0	2	6	6
	Simulated High	376	160	167	197	141	177	64	107	97	147	226	337
	Low	15	24	4	8	7	11	0	0	0	4	9	5
A (%)	Measured	1.00	1.00	1.00	1.00	1.00	1.00	.89	.89	.94	1.00	1.00	1.00
	Simulated	1.00	1.00	1.00	1.00	1.00	1.00	.90	.94	.98	1.00	1.00	1.00

Table 1.7.--A summary of a 50-year simulation of monthly precipitation at gate site 163X20.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Monthly (mm)	Measured	204	119	115	102	60	58	16	31	30	65	144	157
Average Monthly excluding years with no precipitation (mm)	Measured	204	119	115	102	60	58	18	35	32	65	144	157
	Simulated	188	118	121	105	54	65	19	30	32	62	128	154
Standard Deviation (mm)	Measured	105	64	70	48	37	33	13	35	23	39	77	89
	Simulated	102	83	70	64	33	41	13	25	25	48	77	88
Range (mm)	Measured High	417	254	273	225	162	117	52	142	81	182	302	378
	Low	69	30	23	19	20	18	0	0	0	2	20	17
	Simulated High	420	348	330	246	167	196	54	115	127	216	401	448
	Low	44	19	12	22	9	10	0	0	0	5	12	25
A (%)	Measured	1.00	1.00	1.00	1.00	1.00	1.00	.89	.89	.94	1.00	1.00	1.00
	Simulated	1.00	1.00	1.00	1.00	1.00	1.00	.90	.94	.92	1.00	1.00	1.00

Monthly values and standard deviations to be used in the simulation procedure: Once the average monthly values have been found, they must be transformed to fit the cube-root normal distribution (Equation 3), which is used to generate the monthly precipitation series. This is done by taking the cube root of the average monthly precipitation and subtracting 0.18 for all months, except August, when 0.33 must be subtracted. These values must be subtracted off because the cube root of the overall average is greater than the average of the cube roots of the individual yearly amounts. The value of 0.33 for August is higher than for the other months because the monthly deviation for August is greater than the other months.

The standard deviation of the cube root is also required to generate a monthly precipitation series. This number is obtained from Figure 1.5 for all months except August. The standard deviation for August is a constant value of 1.014 because elevation has very little effect on the monthly precipitation amounts and a considerable amount of the precipitation is due to thunderstorms. The high monthly standard deviation during August is also due to thunderstorm precipitation.

The relationships between the average of the cube roots of monthly precipitation and the standard deviation of the cube roots of monthly precipitation are now being investigated on a statewide basis. These results will indicate how well the results from the Reynolds Creek Watershed can be extended to other areas.

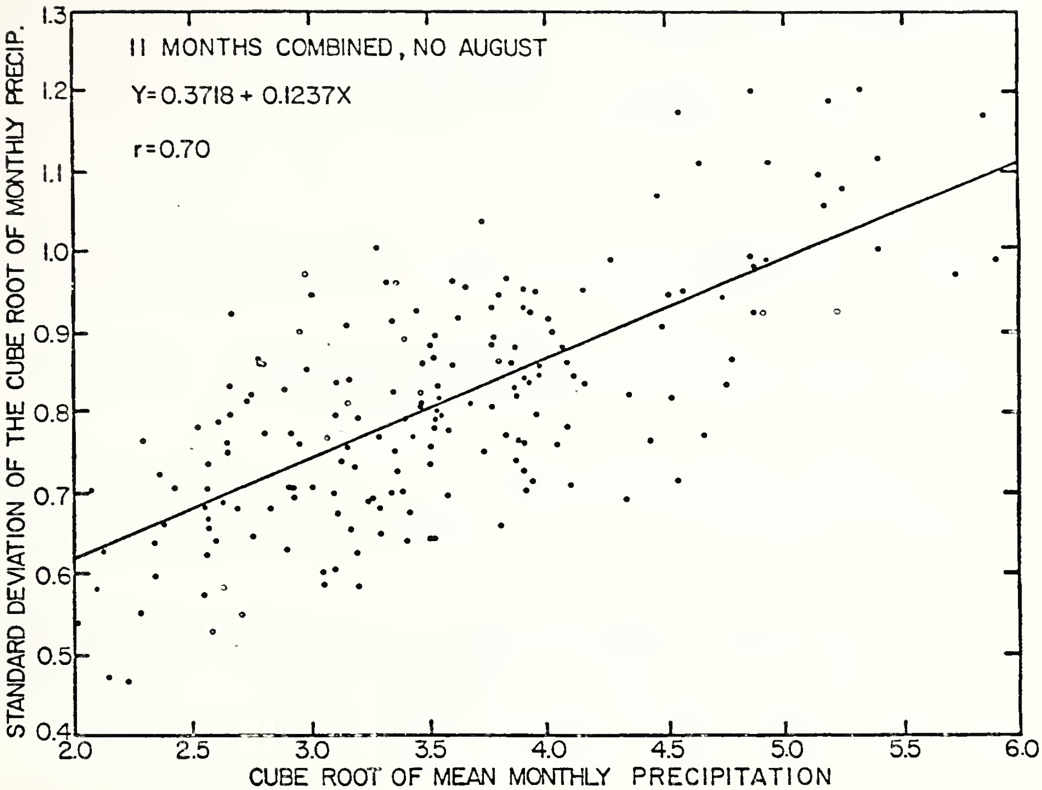

Figure 1.5.--Relationship between the cube-root of the mean monthly precipitation and the standard deviation of the cube-roots of monthly precipitation.

Examples of Annual and Monthly Precipitation Simulation

Annual: Estimate the mean annual and standard deviation at the 1500 m elevation on the west side (downwind side) of Reynolds Creek Watershed.

1. From Equation 5, the mean annual precipitation is 537 mm.

2. The $u_{\ell nx}$ value required in Equation 2 is $\log_e(537) - .02 = 6.266$.

3. The standard deviation ($\sigma_{\ell nx}$) required in Equation 2 is 0.21. This value is a constant for annual precipitation generation.

4. Then generate as many years as is needed from the following equation:

$$Y = \exp(6.266 + .21y) = \text{annual precipitation in (mm)}.$$

5. Values of y are obtained from a table of pseudo-random normal deviates (N(0,1)) or from a computer program that generates these values.

Monthly: Estimate the mean January precipitation and standard deviation at the 1500 m elevation on the west side (downwind site) of Reynolds Creek Watershed.

1. From Table 1.3, the mean monthly precipitation (u in Equation 4) is u = -157 + 0.164 (1500 m) = 89 mm.

2. The cube root of 89 is 4.465.

3. The standard deviation (σ) used in Equation 4 is taken from Figure 1.5 and is 0.914 for a value of u = 4.465.

4. Generate as many years of record as is needed for the study from Equation 4 using the following equation:

$$Y = (4.465 + 0.914y)^3.$$

5. Values of y are obtained from a table of pseudo-random normal deviates (N(0,1)) or from a computer program that generates these values.

6. If the month under study had been July, August, or September, the first step for monthly generation would have been to determine if there was precipitation or not.

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Reynolds Creek precipitation - 1980 (Reynolds Creek site locations are shown in Introduction, Figure 1).

The four precipitation sites listed in Table 1.8 represent the precipitation conditions that existed on the watershed. The water year precipitation ranged 2.3 inches above average at the low elevation site 076X59 (3965 ft.) to 0.3 inch below average at the high elevation site 176X07 (6760 ft.). Above average precipitation during May and September was the reason for the water year's totals being at or above average. The winter (November through April) precipitation was about 20 percent below average and the summer (May through October) was about 50 percent above average.

Electric clocks: Electric clocks were installed in all of the standard weighing and recording precipitation gages. This has allowed us more flexibility in the routine chart changing schedules. These clocks have been very reliable over the past year.

Wyoming shield gage study: The evaluation of the Wyoming shield was continued at sites 076X59, 127X07, and 167X07. The data from these sites are being reduced and analyzed at the present time. This study will be continued at least through the spring of 1981, when all of the data will be analyzed. If there are enough data for a complete evaluation of the Wyoming shield gages as they relate to the dual-gage system, the study will be terminated.

Heated precipitation gages: A study was initiated during the fall of 1980, to determine if the snow catch by heated precipitation gages is comparable with that of standard weighing and recording gages. This study was initiated because there are several companies manufacturing heated gages and their usefulness needs to be evaluated in areas where a major portion of the annual precipitation falls as snow.

Boise Front precipitation - 1980 (Boise Front site locations are shown in Introduction, Figure 2).

The 1980 water year precipitation for the four sites on the Boise Front and the Boise Airport are listed in Table 1.9. The 1977-1980 average precipitation amounts at three sites and the 1978-1980 average at site 328X86, along with the 40-year average at the Boise Airport, are also listed in the Table. The 1980 water year precipitation was greater than the 1977-1980 average and ranged from 3.8 inches at site 328X86 to 6.7 inches at 314X50. The above average precipitation was due to the much above average precipitation in October, May, and September. At the Boise Airport, the water year precipitation was about 34 percent above average. These data show that the precipitation on the Reynolds Creek Watershed and the Boise Front was above average and that the Boise Front was wetter than the Reynolds Creek Watershed.

Table 1.8.--Water year precipitation (inches) at four locations on Reynolds Creek Watershed.[1]

Site	Elevation (ft)	Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Total
076X59	3965	1980	1.034	0.587	0.406	1.713	0.807	0.801	0.877	3.671	0.916	0.220	0.060	2.553	13.645
		1963-1980	0.869	1.192	1.185	1.557	0.781	0.908	0.951	0.846	1.361	0.287	0.784	0.596	11.317
116X91	4760	1980	1.970	1.247	0.989	3.262	1.407	1.909	0.856	3.160	1.136	0.420	0.120	2.849	19.325
		1963-1980	1.475	2.109	2.339	2.779	1.523	1.688	1.729	1.241	1.610	0.403	0.736	0.830	18.462
155X07	5410	1980	3.418	2.719	1.471	5.143	3.096	2.931	1.022	3.521	1.519	0.829	0.140	3.275	29.084
		1963-1980	2.044	3.517	3.740	4.732	2.695	2.748	2.329	1.745	1.870	0.626	1.085	1.070	28.201
176X07	6760	1980	3.404	5.118	2.976	7.295	4.656	5.346	1.639	5.076	1.722	0.908	0.150	3.084	41.374
		1963-1980	2.282	5.536	5.942	8.160	4.484	4.216	3.541	2.410	2.220	0.592	1.155	1.154	41.692

1/ Raingage locations are shown on Introduction, Figure 1.

Table 1.9.--Water year precipitation (inches) at four locations on the Boise Front, and the Boise Airport.

Site	Elevation (ft)	Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Total
328X86[1]	2880	1980	1.602	1.599	0.818	2.214	1.498	2.720	1.352	5.081	0.775	0.030	0.060	2.555	20.304
		1978-1980	0.607	1.606	1.521	2.213	1.765	1.543	1.985	2.371	0.635	0.230	0.469	1.588	16.533
322X62	3800	1980	2.312	2.240	1.407	3.009	2.589	4.186	1.434	6.159	0.865	0.060	0.100	2.184	25.545
		1977-1980	0.846	1.532	1.606	2.337	2.157	2.195	1.978	2.767	1.301	0.305	0.578	1.419	19.021
314X50	4650	1980	2.450	3.189	2.117	3.694	3.026	4.205	1.555	6.048	0.850	0.100	0.110	2.476	29.820
		1977-1980	0.887	2.150	2.131	3.256	2.809	2.582	2.116	2.917	1.405	0.447	0.795	1.615	23.110
311X94	5450	1980	2.673	3.147	1.743	3.965	2.935	4.721	1.674	6.946	0.893	0.080	0.050	2.125	30.952
		1977-1980	1.021	2.147	2.290	2.822	3.074	2.873	2.669	3.340	1.249	0.422	0.808	1.596	24.311
Boise Airport	2838	1980	1.500	1.300	0.690	1.560	1.290	2.140	1.200	3.770	0.580	0.030	0.000	1.590	15.650
		1977-1980	0.560	1.090	0.960	1.630	1.140	1.230	1.330	1.800	0.650	0.230	0.700	0.930	12.250
		1941-1980	0.840	1.320	1.350	1.490	1.150	1.080	1.150	1.240	1.010	0.210	0.340	0.520	11.700

1/ Gage installed February 1977.

Saval Ranch: SEA-AR involvement in the hydrologic aspects of the BLM Saval Ranch Project increased considerably this past year. The initial effort was to assist in the development of the hydrologic work plan for the project. A working session was attended by Cliff Johnson and Keith Cooley on February 19-21 in Denver, Colorado. A plan was drafted by BLM after this session; it was then reviewed and changes were made by those attending. The plan was presented to members of the steering committee and other work groups at a meeting in Elko on April 7-10. Keith Cooley attended this session and chaired a committee assigned to modify the hydrology plan and consolidate ideas from BLM, FS, UNR, and the Saval Ranch management. A revised plan was produced and submitted to BLM in Denver for final writing and approval, prior to submission to the Steering Committee, where it was accepted with minor modifications for implementation.

A second working session was attended by Cliff Johnson and Keith Cooley in Elko on September 8-11. At this session, aerial photos and topographic maps of the ranch were studied, and field observations were made to determine size and location of study watersheds and plots. A few of the better potential sites were visited and one watershed site was selected for instrumentation in October or November. Hydrologic instrumentation, heat needs, and maintenance problems were discussed in detail.

On October 29 and 30, Dave Robertson and Ron Morris, Hydrologic Technicians from the NWWRC, visited the Saval Ranch project to assist Neil Hutten, UNR, in checking and calibrating raingages prior to the winter season. This effort was initiated when raingage equipment problems were detected while marking the charts for the period July through November, 1979. As a result of this trip, several recommendations and plans were made for insuring good data.

In an attempt to centralize data processing and to make best use of existing equipment and personnel, it was decided that the hydrologic data collected at the Saval Ranch project should be processed at the Northwest Watershed Research Center in Boise. Five months of charts from the 11 precipitation measuring sites were, therefore, sent to Boise for processing. Since arrangements to obtain additional help have not materialized, the charts were checked and marked by existing personnel, and only monthly totals for six sites, and a sample of intensity and storm-total analysis was made for 4 days at one site. Output from this sample processing is presented in Tables 1.10 through 1.12, and a map of the Ranch, showing location of the precipitation gages, is presented in Figure 1.6.

Table 1.10 shows that monthly totals were somewhat random during the summer months when precipitation was mainly produced by thunderstorms. Orographic effects dominate during the winter when precipitation is mainly in the form of snow, when the higher stations 5 and 9 received two to three times that of the lower stations.

Table 1.10.--Monthly Precipitation in Inches for Selected Sites at the Saval Ranch Study Area

	Site #1	Site #3	Site #5	Site #8	Site #9	Site #11
1979						
July	0.83	0.68	1.00	1.10	1.33	0.81
Aug.	0.63	0.78	1.27	0.90	1.64	0.93
Sept.	0.58	0.41	0.46	0.61	0.44	0.41
Oct.	1.23	1.75	4.69	2.09	3.54	1.40
Nov.	1.14	0.96	2.74	0.85	2.32	1.18

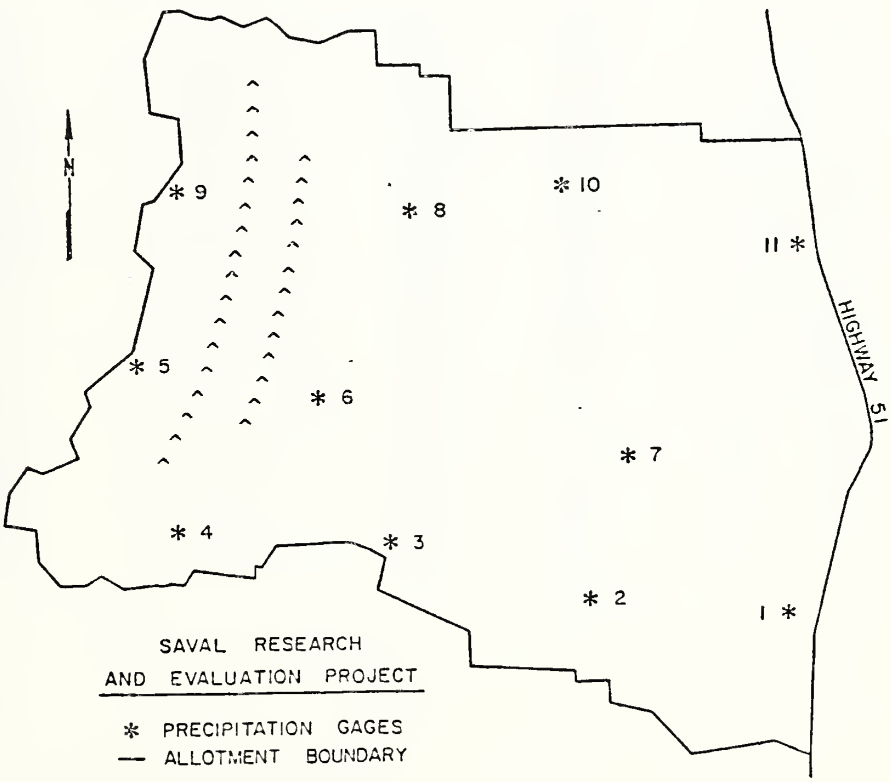

Figure 1.6.--Location of precipitation gages, Saval Research and Evaluation Project, Elko, Nevada.

Table 1.11 shows the amount of precipitation occurring at specific times, the intensity at which it fell, and the total amount accumulated up to that time. The data for a storm of slightly over 30 hours duration are presented, along with daily totals inserted at the end of the day or immediately after the 2400-values.

Table 1.11.--Break Point Precipitation and Intensities for Saval Ranch Experimental Watershed.

MO	DA	YR	MLTM TIME	PRECIP AMOUNT	INTENSITY (IN/HR)	STORM ACCUM. (INCHES)
10	18	79	1840	0.000	0.000	0.000
10	18	79	1856	0.020	0.075	0.020
10	18	79	1939	0.000	0.000	0.020
10	18	79	1953	0.010	0.043	0.030
10	18	79	2309	0.030	0.009	0.060
10	18	79	2400	0.088	0.104	0.148
10	18	79	DAILY TOTAL	0.148		
10	19	79	59	0.102	0.104	0.250
10	19	79	141	0.120	0.171	0.370
10	19	79	152	0.000	0.000	0.370
10	19	79	252	0.110	0.110	0.480
10	19	79	425	0.030	0.019	0.510
10	19	79	442	0.040	0.141	0.550
10	19	79	522	0.040	0.060	0.590
10	19	79	630	0.140	0.124	0.730
10	19	79	715	0.020	0.027	0.750
10	19	79	730	0.070	0.280	0.820
10	19	79	804	0.000	0.000	0.820
10	19	79	817	0.080	0.369	0.900
10	19	79	835	0.000	0.000	0.900
10	19	79	850	0.050	0.200	0.950
10	19	79	912	0.030	0.082	0.980
10	19	79	920	0.060	0.450	1.040
10	19	79	1128	0.000	0.000	1.040
10	19	79	1157	0.020	0.041	1.060
10	19	79	1219	0.140	0.382	1.200
10	19	79	1301	0.150	0.214	1.350
10	19	79	1320	0.040	0.126	1.390
10	19	79	1447	0.040	0.028	1.430
10	19	79	1558	0.120	0.101	1.550
10	19	79	1720	0.100	0.073	1.650
10	19	79	2023	0.070	0.023	1.720
10	19	79	2059	0.060	0.100	1.780
10	19	79	2210	0.030	0.025	1.810
10	19	79	2322	0.000	0.000	1.810
10	19	79	2400	0.037	0.058	1.847
10	19	79	DAILY TOTAL	1.699		
10	20	79	14	0.013	0.056	1.860
10	20	79	31	0.050	0.176	1.910
10	20	79	112	0.040	0.059	1.950

10 20 79 1 MIN INTEN(5, 10, 15, 20, 30) 0.450 0.382 0.382 0.382 0.337

10 20 79 1 HR INTEN(1, 2, 4, 6, 12, 24) 0.276 0.177 0.122 0.105 0.091 0.073

Definition of Storm, Precipitation storm accumulations which are equal to or greater than 0.25 inches and where no time periods of precipitation were zero for more than 4.00 hours.

Table 1.12 presents the daily total for each day of the year, as well as monthly and yearly totals. In this case, since only 4 days' data were processed, all daily values are zero except for October 18 through 21, as shown.

Figure 1.6 shows the Ranch Allotment Boundary and the location of the precipitation sites. The ground rises gently from the highway on the east boundary to the foothills, which are just west of sites 3, 6, and 8. Sites 5 and 9 are in the mountains, and are about 2000 feet higher than the other sites. Site 4 is in a canyon, which drains portions of the mountain.

Processing of the remainder of the data, as well as that collected during 1980, can commence when additional help is available.

Table 1.12.--Daily, monthly, and yearly summary of precipitation, using actual break points for the year 1979.[1/]

SAVAL RANCH EXPERIMENTAL WATERSHED

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2
3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3
4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4
5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5
6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6
7	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	8
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	9
10	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	10
11	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	11
12	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	12
13	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	13
14	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	14
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	15
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	16
17	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	17
18	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.148	0.000	0.000	18
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.699	0.000	0.000	19
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.273	0.000	0.000	20
21	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.140	0.000	0.000	21
22	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	22
23	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	23
24	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	24
25	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	25
26	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	26
27	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	27
28	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	28
29	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	29
30	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	30
31	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	31
TOTAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.260	0.000	0.000	

YEARLY TOTAL 2.260

[1/] Only October 18-21 were processed.

2. VEGETATION

Personnel Involved

J. R. Wight, Range Scientist	Plans, designs, and supervises field studies and coordinates research activities and prepares reports.
C. L. Hanson, Agricultural Engineer	Performs computer analyses relative to field studies and assists in planning field studies.
K. R. Cooley, Hydrologist	Plans, designs, and supervises soil water modeling.
J. P. Smith, Hydrologist	Assists in vegetation data reduction.
D. C. Robertson, Hydrologic Technician	Supervises hydrologic data reduction and performs computer operations.
D. L. Coon, Hydrologic Technician	Assists in data collection and noting field observations, including soil moisture measurement and calibration.
C. Miller, Cooperator (BSU)	Assists in hydrologic data reduction.

Reynolds Creek (Reynolds Creek site locations are shown in Introduction, Figure 1).

Soil water balance models: Progress related to the testing of Wight's and Saxton's soil water balance models consisted of; (1) obtaining copies of the models, and transforming the language and/or format so that they are compatible with our computer system; (2) preparing a calibration and test data set; and (3) making a preliminary computer run or test to insure the models are working properly.

Magnetic tape copies of both models have been obtained, and both have been entered into the computer. Wight's model has been transformed from BASIC to FORTRAN and checked against a control data set. Saxton's model is in FORTRAN, but will require some format revisions before it will run on our computer system.

The two models are quite different with respect to both complexity and data requirements. Wight's model is relatively simple and requires about the minimum of input information. Saxton's model, on the other hand, attempts to treat in some detail, all of the physical processes and interactions involved. As such, it requires more information on initial boundary conditions and limits. However, both use essentially the same hydrologic and meteorological data. Testing of these two models should indicate the amount of sophistication necessary to obtain adequate estimates of soil water status for various field watershed applications.

Hydrologic and meteorological data for four subwatersheds on the Reynolds Creek Experimental Watershed are being assembled for testing the models. This data set will cover the 1975 through 1980 period for two lower elevation sites, one mid-elevation site, and a high elevation site, with their associated vegetation, climate, and soil differences. One year's data will be used to calibrate the models, and the other 5 years' will be used as a test. Data will include daily values of precipitation, runoff, incoming solar radiation, and maximum and minimum temperature. Daily values of pan evaporation, when available, will also be included. Actual soil moisture data are available as a check at approximately 2-week intervals, and five soil depths at all four sites.

Data for the Flats and Lower Sheep Creek sites are in the final stages of being listed, verified, and entered into the computer. Data for the Nancy and Reynolds Mountain sites are being processed, and a limited file will be available for computer entry in the near future. Processing of data for these sites will continue. Data reduction has required considerable effort during the past year, since almost all of the solar radiation data was still on strip charts and required planimetering to obtain daily totals. The soil moisture data required plotting, verification, and, in some cases, adjustment to compensate for variation

between probes, etc. It was also necessary to process some temperature and evaporation data, to fill in gaps in temperature, evaporation, and solar data, and to compile files of the data in suitable format for use with the models.

A preliminary computer run was made with Wight's model, using most of the data for 1979 at the Flats site. Although this was not considered a good test or calibration run for the model, because most of the information needed to establish good boundary conditions was not yet on hand, the results are presented in Figure 2.1, to indicate output from the models. Boundary condition information needed are: plant types and growth characteristics, soil characteristics by layers, soil temperature relations by layers, thickness of layers, soil moisture holding capacity, and initial soil moisture. This information is being gathered and calibration and evaluation runs using both models will be made within the coming year. As noted in Figure 2.1, the trends predicted by the model are similar to those obtained by soil moisture measurements. For this preliminary run, vegetation growth curves and soil temperature relations, at all five levels, were represented by simple sine wave relationships. Considerable improvements in results are anticipated when actual growth and temperature relations, and known soil physical characteristics are used.

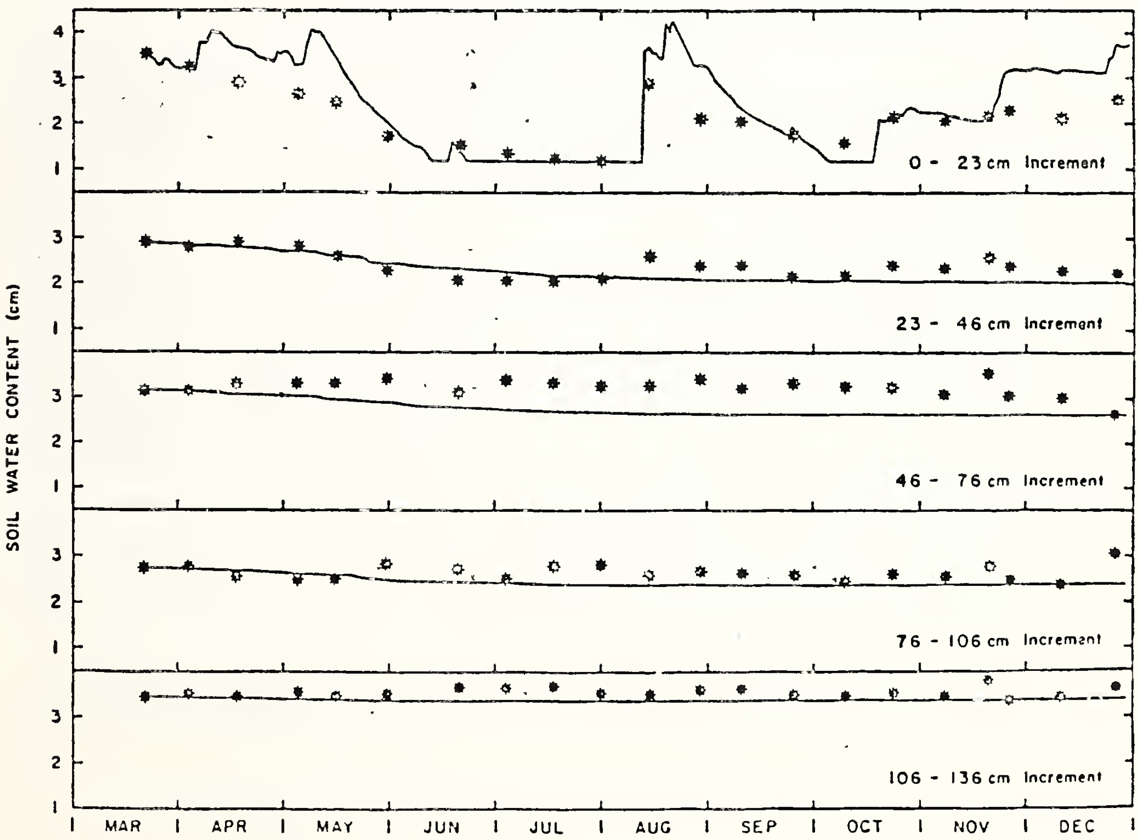

Figure 2.1.--Flats Site 1979 - Field-measured (represented by asterisks) and model-predicted (solid line) soil water content for five layers from the surface to 136 cm depth.

The preliminary calibration and evaluation of Wight's model was the start of our program to predict soil moisture stress and associated forage yield forecasting. This is a program that is continuing and more emphasis will be put on forage yield modeling when the complete set of hydrologic field data, that was discussed in the previous paragraphs, has been assembled.

Boise Front [Boise Front Watershed study site locations are shown on Introduction, Figure 2. Pastures are referred to throughout the report as H (High) and L (Low)].

Cattle use: On April 15, 206 cows, calves, and bulls were turned into L1 (Tables 2.1 and 2.2). The cattle spread over the area and forage utilization was uniform over the pasture. Because of good growing conditions, the cattle were not moved to H1 (Pickett Pin segment) until June 9. On July 14, 45 head were moved off the grazing allotment and the other 161 head were moved into the rest of H1.

Table 2.1.--Grazing schedule and type of management for Boise Front pastures.

Year	Pasture			
	High or Low, 1	High or Low, 2	High or Low, 3	High or Low, 4
1978	C Early Rest (until seed ripe) (Graze Picket Pin 4/1-5/8)	A Graze Season Long	D Rest Season Long (seedling establishment)	B Rest Season Long (for plant vigor)
1979	D Rest Season Long (seedling establishment)	B Rest Season Long	A Graze Season Long	C Early Rest (until seed ripe)
1980	A Graze Season Long	C Early Rest (until seed ripe)	B Rest Season Long (for plant vigor)	D Rest Season Long (seedling establishment)
1981 (1977)	B Rest Season Long (for plant vigor)	D Rest Season Long (seedling establishment)	C Early Rest (until seed ripe)	A Graze Season Long

Table 2.2.--Dates cattle grazed Boise Front pastures during 1980.

Pasture	Cattle Grazing Dates	Time for[1/] Cattle to move Between Pastures
Low 1	April 15-June 9	
High 1 (Pickett Pin)	June 9-July 14	June 9-15
High 1	July 14-August 18	July 14
High 2	August 18-October 10	August 18-27
Low 2	October 10-November 11	Cattle drifted from High 2 to Low 2 during this period.
Low 2	November 11-November 21	Cattle moved off during this period.

[1/] Dates indicate opening and closing of gates.

The cattle were moved to H2 between August 18 and 27. During the period, August through November, there were problems with cattle getting out of the designated pasture and returning to the lower part of L1. The cattle were moved back to H2 many times during this period. This problem was accelerated during hunting season, because gates were left open.

The gate between H2 and L2 was opened on October 10 to let the cattle drift into L2. Most of the cattle were in L2 by November 11, when some cattle started to move off the project. All cattle, except 13 stray cows and calves, were off the project on November 21.

A randomly selected group of the calves was weighed on April 4 and again on November 13. The calves gained more weight during 1980 than during 1979 (Table 2.3).

Table 2.3.--Rate of gain of randomly selected cattle during 1980[1/]

	AVERAGE		RANGE	
	Rate of Gain	Pounds Gained	Rate of Gain	Pounds Gained
	Pounds Per Day		Pounds Per Day	
Calves	1.04	233	.62-1.60	140-355
Heifers Calves	1.00	225	.62-1.52	140-340
Steers Calves	1.08	242	.67-1.60	150-355

[1/] Spring weighing-April 4, 1980.
Fall weighing-November 13, 1980.

Sheep use: Two bands of 2100 ewes and lambs used the Boise Front during the spring and fall of 1980. One band moved into H1 on May 7, crossed H2, upper part of L2, to upper part of L3, and left the project on May 30, after crossing the middle part of H3. The second band spent 3 days trailing across H2 and L3.

One band entered H4 on November 3, crossed H3, then L3, along the edge of H2, and then crossed L1. This band left the project at Spring Creek on November 30.

Deer use: The Boise Front project serves as a winter deer range where bitterbrush is one of the main browse plants. There were an estimated 2580 deer throughout the project at the time of the January 1980 count. Utilization information was collected during the spring of 1980, the results of which are listed in Table 2.4. At least 49 percent of all available leaders were utilized on all pastures. Twig length utilization was least in L2 and greatest in L4.

Utilization information was not obtained after the cattle were moved off L1, so there is no spring cattle utilization as we have had in previous years.

Table 2.4.--Bitterbrush utilization on the Boise Front pastures during 1980.

Pasture	Percent of Available Twigs Showing Hits	Percent of Total Utilization[1/]
Low 1	50	20
Low 2	49	15
Low 3	65	32
Low 4	67	27

[1/] Use of annual growth equals percent of twigs taken times percent of available leaders used.

Frequency percentage, overstory, and basal cover: Species frequency and cover were collected at the rotation grazing study sites in pastures L1 and L2. The site in pasture L3 was not sampled because of a lack of personnel. The presence of any plant species occurring within a 18-in^2 quadrat was identified. One hundred quadrat placements were used at each of the exclosures and rotation grazed treatments at each site. Species frequency percentage is listed in Table 2.5. This was the fourth year frequency data were obtained and no noticeable differences between treatments have been observed.

Overstory measurements were collected in 1980, with a summary of the 1977 through 1980 surveys listed in Table 2.6. There were no noticeable differences between the treatments.

Percent basal cover for the years 1977 through 1980 is listed in Table 2.7. These data have not been analyzed for treatment differences.

Table 2.5.--Frequency percentage of plant species within exclosure and on adjacent rotation grazing pastures.

	Pasture					
	3221 Low 1		3272 Low 2 (Maynard Gulch)[1/]		3222 Low 2 (Pond Spring)[1/]	
	Exclosure	Rotation Grazed	Exclosure	Rotation Grazed	Exclosure	Rotation Grazed
Agropyron species						
Agropyron intermedium						
Agropyron spicatum			1	5		
Aristida longiseta	10	5				2
Bromus tectorum	88	99	96	95	94	68
Bromus spp.			1	1		
Festuca arida			18		9	
Festuca megalura	61	41	62	53	55	64
Poa sandbergii	82	88	100	97		1
Sitanion hystrix	64	60	80	59	9	10
Taeniatherum caput-medusae			3	16	100	100
Achillea millefolium lanulosa	1			2		1
Agoseris species						
Amsinckia retrorsa	11	17	61	11		
Antennaria dimorpha						
Apocynum cannabinum			3		2	8
Astragalus purshii	10	9	19	12		
Balsamorhiza sagittata		1				
Blepharipappus scaber	68	57	65	38		
Calohortus macrocarpus	1				3	
Cirsium canouirens						
Crepis acuminata			1			3
Crepis occidentalis	32	4	1	1	8	3
Cryptantha species						
Descurainia spp.	5				9	
Epilobium spp.			2			
Epilobium paniculatum	76	77	71	93	10	30
Eriogonum spp.	19	23	5	19		1
Erodium circutarian	67	80	46	30	62	90
Erigeron				3		
Erigonum uimineum						
Helianthus species		1	19	2	3	35
Holosteum umbellatum						
Lagophylla ramosissima	51	74	63	82		3
Lactuca serriola	10	14	6	10	92	73
Lepidium species	50	38	93	100	22	13
Lomatium nudicaule			3	3		
Lomatium triternatum platycarpum						
Lupin species			3	4		
Microseris species			1	1		
Myosatis species	7	18	20	64	6	
Phlox species	11	9	9	20		
Plectritis macrocerna						
Polygonum majus						
Thysanocarpus curvipes			2			
Tragopogon dubius		2				
Forb						1
Artemisia tridentata						
Chrysochamnus nauseosus albicaulis				1		

1/ Grazed 1979.

Table 2.6.—Percent overstory for different cover components at four rotation pasture sites in 1977, 1978, 1979, and 1980.

	Pasture														
	3221 Low 1				3272 Low 2 (Maynard Gulch)				3222 Low 2 (Pond Spring)				3363 Low 3[1/]		
	1977	1978	1979	1980	1977	1978	1979	1980	1977	1978	1979	1980	1977	1978	1979
VEGETATION TOTAL															
Exclosure	26	46	25	80	41	43	41	68	47	59	39	100	37	43	30
Rotation Grazed	33	58	22	81	33	41	38	79	58	76	61	100	52	46	36
LITTER															
Exclosure	24	21	27	5	19	6	19	9	48	34	55	0	27	14	17
Rotation Grazed	14	3	25	1	18	5	18	4	36	21	34	0	17	18	32
ROCK															
Exclosure	11	14	6	12	2	3	5	14	0	1	1	0	5	6	4
Rotation Grazed	15	11	9	13	3	2	3	2	2	1	1	0	6	4	2
BARE GROUND															
Exclosure	39	17	42	3	33	48	35	9	5	6	4	0	31	37	49
Rotation Grazed	38	28	44	5	46	52	41	15	4	3	4	0	25	32	30

1/

Table 2.7.—Percent basal cover for different components at four rotation pasture sites in 1977, 1978, 1979, and 1980.

	Pasture														
	3221 Low 1				3272 Low 2 (Maynard Gulch)				3222 Low 2 (Pond Spring)				3363 Low 3[1/]		
	1977	1978	1979	1980	1977	1978	1979	1980	1977	1978	1979	1980	1977	1978	1979
VEGETATION TOTAL															
Exclosure	17	7	11	7	32	24	18	12	15	22	24	1	18	15	14
Rotation Grazed	28	19	6	4	20	27	18	20	8	28	10	3	9	12	13
LITTER															
Exclosure	32	28	30	40	23	12	26	21	78	64	67	97	36	28	25
Rotation Grazed	19	8	32	28	24	10	27	34	85	65	82	95	59	40	44
ROCK															
Exclosure	11	33	7	45	3	4	7	43	2	2	1	2	5	8	4
Rotation Grazed	13	17	11	55	4	4	4	5	2	1	1	1	6	6	3
BARE GROUND															
Exclosure	40	32	52	8	42	60	49	24	5	17	8	0	41	49	57
Rotation Grazed	38	56	51	13	52	59	51	41	5	6	7	1	26	42	40

1/

3. RUNOFF

Personnel Involved

C. W. Johnson, Research Hydraulic Engineer	Plans programs and procedures; designs and constructs facilities for runoff studies; performs analyses and summarizes results.
D. L. Brakensiek, Research Hydraulic Engineer	Streamflow and infiltration modeling.
A. L. Huber, Hydrologist	Runoff analyses and modeling.
C. L. Hanson, Agricultural Engineer	Tests various components in runoff models most applicable to rangelands.
G. R. Stephenson, Geologist	Groundwater.
J. P. Smith, Hydrologist	Streamflow data collection, quality control, processing, and analyses.
R. L. Engleman, Mathematician	Performs data compilation and assists in analyses.
R. P. Morris, V. M. Aaron, Hydrologic Technicians, and M. Campbell, Hydrologic Aid	Performs data compilation and and processing.
M. D. Burgess, Electronic Technician	Designs, constructs, and services electronic sensors and radio telemetry systems.
K. R. Cooley, Hydrologist	Snowmelt runoff.
D. C. Robertson, Hydrologic Technician	Snowmelt runoff.

Mean annual precipitation is often used as an index for generalizing mean annual runoff from small watersheds in mountainous areas, where the major differences in precipitation patterns and water yields are due to elevation and topography. In mountainous areas, mean annual precipitation can often be used as a single and comprehensive indicator of mean annual runoff if it is well defined. Figure 3.1 shows the relationship between mean annual precipitation and mean annual runoff for 11 watersheds at Reynolds Creek. Despite the few points at the higher values, there is a definite positive correlation between mean annual precipitation and mean annual runoff. There is very little runoff where annual precipitation is less than 400 mm.

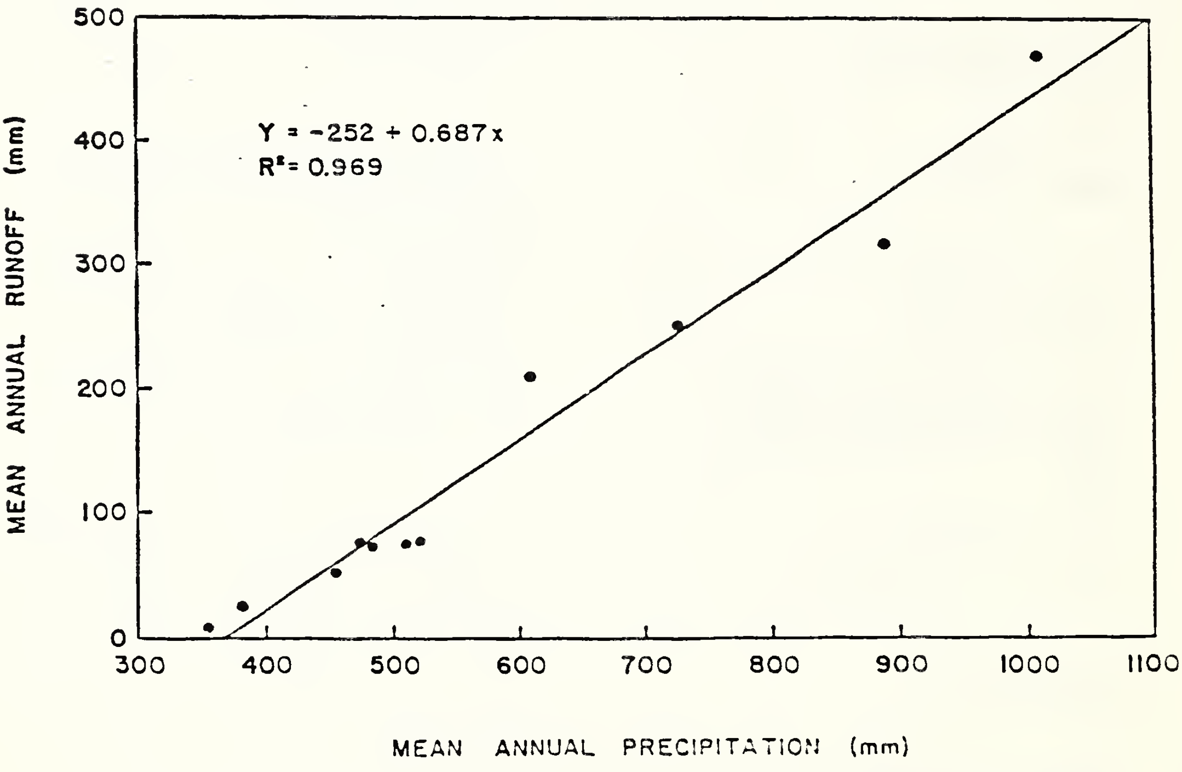

Figure 3.1.--Precipitation-Runoff relationship, Watersheds on Reynolds Creek.

Riggs and Moore (1965) recognized the large differences in runoff due to elevation in the mountainous areas of Nevada. They determined mean annual runoff values by elevation zones for five different regions within a study area in northern Nevada. The five regions were differentiated and identified by different precipitation-elevation curves. Figure 3.2 shows the five curves for Nevada and two for the Reynolds Creek Watershed. The Reynolds Creek precipitation data were divided into east and west sites, according to the different precipitation-elevation relationships. The two sets of data show the large differences in annual precipitation due to elevation and orientation. The Reynolds Creek eastern sites seem to fit somewhere between Nevada curves D and E, while the Reynolds Creek western sites show far greater precipitation per elevation zone than any region in Nevada. Some of the large difference between Reynolds Creek and Riggs and Moore precipitation-elevation relationships may be caused by data sources. The Reynolds Creek precipitation data were obtained from an intensive raingage network, designed for detailed hydrologic analysis, while Riggs and Moore data were determined from a limited weather station network and snow courses where available.

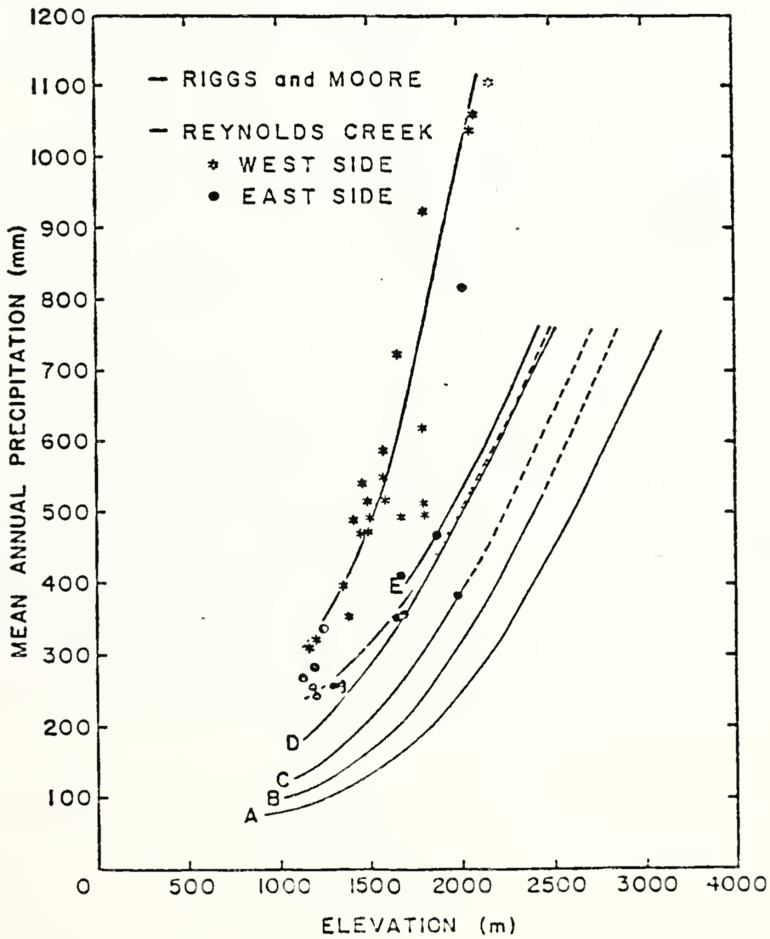

Figure 3.2.--Elevation-precipitation relationships.

Table 3.1 shows runoff values by elevation zones for the five regions in Nevada and the eastern and western sites in Reynolds Creek. The runoff values on the Reynolds Creek eastern sites fall somewhere between Nevada regions D and E, as on the precipitation elevation curve. The runoff values on the western Reynolds Creek sites average about five times the values on the eastern Reynolds Creek sites.

Table 3.1.--Runoff by elevation zones.

ELEVATION ZONE	RUNOFF (MM PER YEAR)						
	NEVADA REGIONS					REYNOLDS	
(METERS)	A	B	C	D	E	EAST	WEST
1219-1524	-	-	-	-	-	0	38
1524-1829	0	0	13	13	41	38	178
1829-2134	0	0	31	76	140	102	559
2134-2438	10	13	76	152	254	-	-
2438-2743	64	81	140	279	406	-	-
2743-3048	142	178	241	406	533	-	-
3048-3353	239	305	356	533	660	-	-
3353-3658	406	457	-	-	-	-	-
3658-3962	-	660	-	-	-	-	-

Mean annual runoff is usually well defined for streams utilized for irrigation. What is of interest on these streams is the variability in annual flows. The relative variability of annual runoff between watersheds in southern Idaho and northern Nevada is illustrated in Figure 3.3. The coefficient of variation, which is the standard deviation divided by the mean, was used as a measure of the relative variability between watersheds. It is evident from Figure 3.3 that variability of annual runoff increases as the mean annual runoff decreases and that the relationship seems to be quite systematic within homogeneous regions. Annual runoff variability within Reynolds Creek probably behaves in a systematic fashion, because 65 to 80 percent of the annual runoff is from frontal type storms.

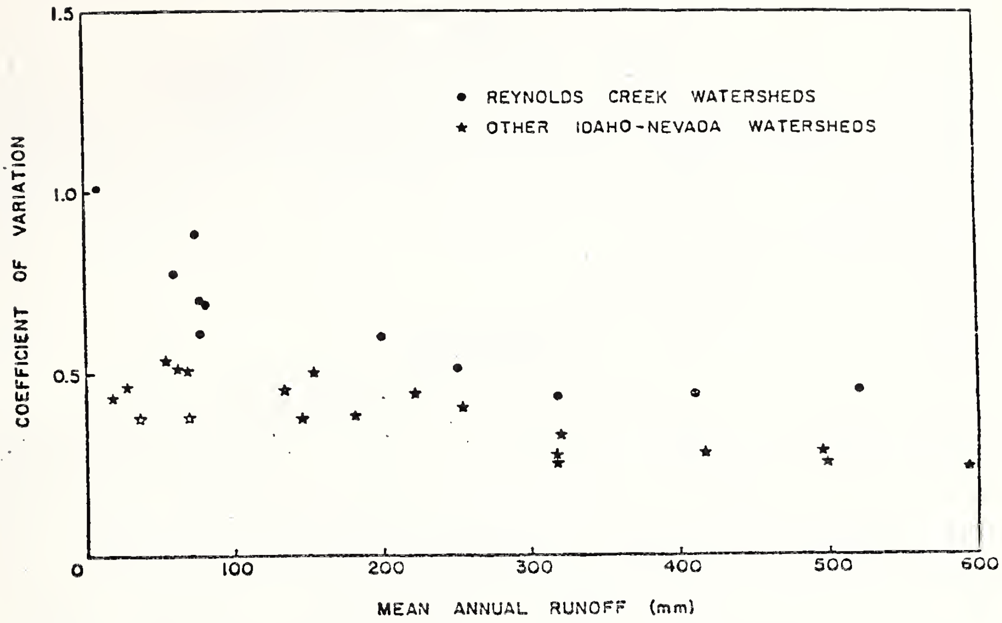

Figure 3.3.--Relationships between mean annual runoff and the coefficient of variation, Idaho - Nevada, and Reynolds Creek Watersheds.

Waitt and O'Neill (1969) investigated the variability of annual river flows in Europe, Australia, and for drainages in latitudes north of 34° N in the United States. Their findings also indicate that the variability of annual river flows is only dependent upon the geometric mean of annual river flows. The relationship that they developed and the 95 percent confidence limits for the rivers that they studied within the United States is shown in Figure 3.4, along with data from the Idaho-Nevada stations.

This relationship between runoff variability and the geometric mean of annual flows would allow one to develop a regional risk diagram, such as Figure 3.5. This figure, developed from Reynolds Creek data, shows the annual runoff exceedances as a function of mean annual runoff for several probability levels. With a mean annual runoff of 240 mm at Tollgate, one can see from this diagram that there is a 20 percent chance of exceeding 260 mm in any given year. Also, there is an 80 percent chance of exceeding 140 mm in any given year (80% exceedance curve).

Relationships, such as shown in Figure 3.5, are needed for estimating the dependable water supply for irrigation and storage, for determining drought frequency, and for other water quality and power generation studies.

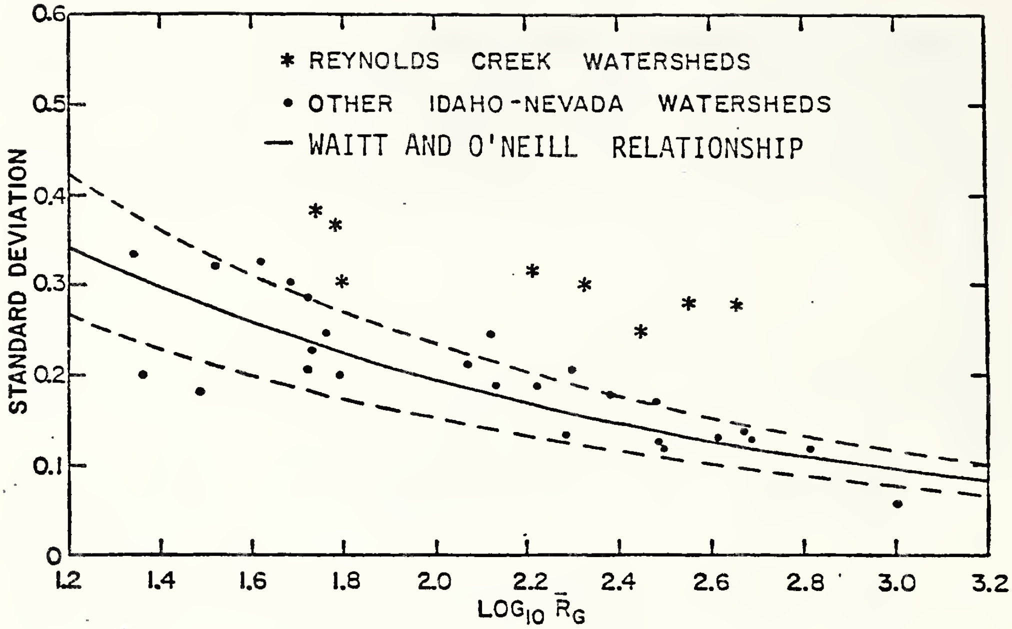

Figure 3.4.--Relationship between variability of annual river flows and mean of annual river flows; and the 95 percent confidence limit for rivers studied.

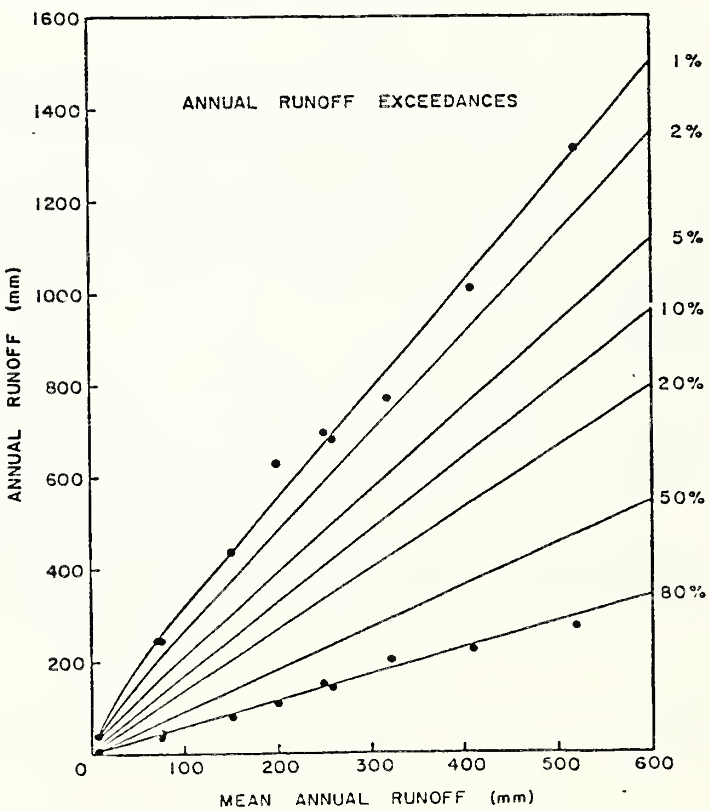

Figure 3.5.--Regional risk diagram for Reynolds Creek Watersheds.

REGIONAL DATA BASE

Computer tapes containing peak flow data for the entire United States, and daily flow data for the Great Basin, the Upper Columbia River Basin, and the Snake River Basin have been purchased from the U.S. Geological Survey. These data files are currently being reformatted, error checked, and edited in preparation for further regional analysis.

REFERENCES

Riggs, H. C., and D. O. Moore. 1965. A method of estimating mean runoff from ungaged basins in mountainous regions. U.S. Geological Survey prof. paper 525-D. p. D199-D202.

Waitt, Frank W. F., and Ian C. O'Neill. 1969. Systematic variation pattern of annual river flows. J. of the Hydraul. Div., Vol. 95, No. HY3, May.

1980 WATER YEAR RUNOFF CONDITIONS

Runoff and peak streamflow were below normal at Reynolds Creek Watershed Stations during the 1980 water year. Peak streamflow from areas below 5,500 feet elevation was greatest January 11-16, when temperatures reached 50° F, the soil was partly frozen, and about 1.6 inches or more of rain fell. However, above 5,500 feet elevation, temperatures were below freezing and runoff was not significant. Peak snowmelt streamflow from areas above 5,500 feet elevation occurred April 21-23, with 50° F temperatures and light rain combined. Peak streamflow at the 90 mi^2 Reynolds Creek Outlet Station occurred May 6 and May 30 from heavy rain.

MICROWATERSHEDS

Flats: Eight separate runoff events were recorded on this 2.24-acre watershed in 1980, Table 3.2. Frozen soil, 40-50° F temperatures, and 0.28 inch precipitation produced 13.2 ft^3 runoff January 11, 1980. Runoff in May, June, and September were caused by heavy rain, usually when soils were wet. Total watershed runoff for the year was only 0.012 inch from all events. Runoff rates ranged from 0.001 to 0.02 ft^3/sec with the maximum on May 6.

Nancy Gulch: Seven separate events on this 3.1 acre-watershed produced only about 0.019 inch of runoff in 1980, Table 3.2. January runoff was caused by frozen soil, warm temperatures, and rain similar to conditions at the Flats Watershed. The largest storm on May 6 produced at least 50 ft^3 runoff, but a recorder malfunction caused loss of the record. Runoff in September was caused by short intense rains and wet soil conditions. The maximum recorded runoff rate was 0.04 ft^3/sec September 13, 1980.

SOURCE WATERSHEDS

Lower Sheep: Runoff from this 33-acre watershed was only 0.01 inch, similar to drought years 1968, 1973, and 1977, Table 3.3. Precipitation was 15.00 inches, about 9 percent greater than the 8-year mean. Peak streamflow rates were mainly from snowmelt and were much below average.

Reynolds Mountain East: Runoff from this 100-acre watershed was 18.89 inches, only about 6 percent below the 18-year mean, Table 3.3. Water year precipitation was 41.37 inches, 99 percent of the mean. Peak streamflow was from snowmelt in April and was slightly lower than the mean of record.

Reynolds Mountain West: Runoff from this 126-acre watershed was 13.36 inches, about 84 percent of the 16-year mean, Table 3.3. Peak streamflow was from snowmelt and about 73 percent of the mean value.

Table 3.2.--Microwatershed runoff data, 1980 water year.

Date	Flats Microwatershed			Nancy Gulch Microwatershed		
	Storm precipitation (inches)	Runoff volume (FT^3)	Peak flow (FT^3/sec)	Storm precipitation (inches)	Runoff volume (FT^3)	Peak flow (FT^3/sec)
Jan. 11	0.28	13.2	0.005	0.32	75.4	0.020
Jan. 12	0.07	0	0	0.14	5.0	0.001
Jan 12	0.22	0	0	0.30	33.1	0.013
May 6	0.56	24.1	0.020	0.85	E 50.0 1/	---
May 15	0.42	10.6	0.003		0	0
May 30	0.32	3.8	0.004		0	0
May 30	0.25	8.3	0.010		0	0
June 3	0.19	2.9	0.005		0	0
Sept. 13	0.32	21.1	0.020	0.28	25.2	0.036
Sept. 13	0.33	12.0	0.001	0.22	2.3	0.001
Sept. 20	0.17	0	0	0.21	21.1	0.029
Total Volume (FT^3)		96.0			212.1	
Total Volume (Inches)		0.012			0.019	

1/ Recorder malfunction, runoff volume estimated.

Table 3.3.--Water year precipitation, runoff, and peak streamflow, source watersheds, Reynolds Creek Watershed.

Water Year	Lower Sheep Watershed Precipitation	Lower Sheep Watershed Runoff	Lower Sheep Watershed Peak Streamflow	Lower Sheep Watershed Date of Peak	Reynolds Mountain East Watershed Precipitation	Reynolds Mountain East Watershed Runoff	Reynolds Mountain East Watershed Peak Streamflow	Reynolds Mountain East Watershed Date of Peak	Reynolds Mountain West Watershed Precipitation	Reynolds Mountain West Watershed Runoff	Reynolds Mountain West Watershed Peak Streamflow	Reynolds Mountain West Watershed Date of Peak
	inches	inches	ft^3/sec		inches	inches	ft^3/sec		inches	inches	ft^3/sec	
1963	16.98	----1/	----	----	37.82	11.11	4.16	Apr. 29	-----2/	-----3/	-----	-----
1964	13.55	----	----	----	40.89	21.02	3.60	May 16	-----	-----	-----	-----
1965	20.86	----	----	----	66.10	34.87	10.70	Dec. 23	-----	25.00	9.29	Dec. 23
1966	6.81	----	----	----	28.36	9.86	1.43	May 5	-----	7.39	1.87	Apr. 8
1967	18.73	0.34	1.41	Jan. 21	50.45	21.01	5.44	May 22	-----	17.18	5.10	May 22
1968	11.30	0.02	0.08	Feb. 18	31.97	6.72	1.48	Aug. 10	-----	6.31	1.97	Feb. 23
1969	14.12	0.52	0.49	Jan. 20	37.45	22.43	3.88	May 12	37.37	17.26	4.20	May 10
1970	14.24	0.02	0.05	Jan. 27	39.60	20.06	5.89	May 17	37.95	20.24	12.33	May 17
1971	17.68	0.31	0.20	Mar. 12	57.96	31.06	5.77	May 4	45.75	21.41	10.24	May 4
1972	13.82	0.91	2.08	Jan. 22	50.51	33.52	6.26	June 6	45.98	29.56	6.31	May 14
1973	12.20	0.01	0.02	Apr. 17	31.01	13.24	3.31	May 8	28.40	10.02	5.35	Apr. 27
1974	10.28	0.26	0.38	Mar. 15	45.54	26.64	4.33	May 7	38.67	19.77	5.61	May 7
1975	14.89	0.73	0.90	Feb. 13	51.57	27.93	9.27	June 2	42.83	21.24	14.28	June 2
1976	14.46	0.55	0.31	Mar. 17	42.51	22.35	4.59	May 13	-----	16.38	4.09	May 2
1977	8.27	0	0	----	21.11	3.44	0.93	Apr. 16	-----	2.31	0.72	Apr. 16
1978	15.13	0.14	0.09	Apr. 27	43.82	23.12	4.50	May 14	-----	17.07	3.52	May 14
1979	9.90	0.34	1.33	Jan. 11	32.42	15.15	3.52	May 15	-----	11.65	3.99	May 4
1980	15.00	0.01	0.09	Jan. 12	41.37	18.39	3.69	Apr. 22	-----	13.36	4.22	Apr. 22
MEAN	13.79	0.30	0.53	----	41.69	20.14	4.60	----	-----	15.99	5.81	-----

1/ Runoff station record began in 1966.

2/ Precipitation record began in 1968 and terminated in 1975.

3/ Runoff station record began in 1964.

Salmon Creek: Runoff from this 8,900-acre watershed was 2.19 inches, less than 72 percent of the 16-year mean, Table 3.4. Peak streamflow, January 12, 1980, from frozen soil, snowmelt, and rain was only about 25 percent of the mean. Water year precipitation was 22.28 inches, about 9 percent above average.

Macks Creek: Runoff from this 7846-acre watershed was 1.64 inches, 68 percent of the 15-year mean, Table 3.4. Peak streamflow, January 12, was about 30 percent of the mean and conditions were similar to Salmon Creek. Precipitation was 20.78 inches, about 5 percent above average.

Dobson Creek: Runoff from this 3,482-acre watershed was 11.48 inches, slightly greater than the 8-year mean, Table 3.4. The watershed drainage includes areas above 7,000 feet elevation where snow courses showed a March 15 snow water equivalent slightly above average. Precipitation was 38.48 inches, about 6 percent above the 18-year mean.

Table 3.4.--Water year precipitation runoff, and peak streamflow, Tributary Watersheds, Reynolds Creek Experimental Watershed.

	Salmon Creek			Macks Creek			Dobson Creek		
Water Year	Precipi-tation	Runoff	Peak Streamflow	Precipi-tation	Runoff	Peak Streamflow	Precipi-tation	Runoff	Peak Streamflow
	inches	inches	ft^3/sec	inches	inches	ft^3/sec	inches	inches	ft^3/sec
1963	22.63	—	—	—	—	—	36.12	—	—
1964	19.90	—	—	—	—	—	32.48	—	—
1965	33.51	9.65	1007	—	—	1200	40.89	—	—
1966	10.27	1.05	10	—	0.61	12	23.78	—	—
1967	22.77	2.24	85	—	1.54	90	39.56	—	—
1968	14.73	0.77	34	—	0.49	44	32.54	—	—
1969	19.36	3.14	209	19.90	2.93	307	40.61	—	—
1970	24.96	3.07	210	19.29	1.92	241	41.67	—	—
1971	24.34	3.61	132	23.65	3.79	281	52.68	—	—
1972	22.74	5.50	201	23.43	4.84	138	42.29	—	—
1973	17.35	2.14	55	15.93	1.76	54	28.93	7.62	49
1974	16.80	3.31	53	15.54	3.72	71	38.94	17.42	82
1975	20.43	3.54	92	22.68	4.79	142	41.85	16.78	65
1976	22.81	2.38	19	21.02	2.67	33	38.37	12.97	43
1977	12.83	0.62	103	14.67	0.43	19	20.62	2.36	9
1978	23.42	3.41	102	24.61	3.01	66	36.30	13.00	66
1979	17.63	2.25	380	16.45	2.10	300	27.31	9.18	31
1980	22.28	2.19	43	20.78	1.64	37	38.48	11.48	42
MEAN	20.49	3.05	169	19.31	2.41	124	36.30	11.41	48.1

MAIN STEM WATERSHEDS

Reynolds Creek Outlet: Runoff from this 57,700-acre watershed was 2.26 inches, 76 percent of the 18-year mean, Table 3.5. Peak streamflow, May 6, was 259 ft^3/sec, about 32 percent of the yearly average and resulted from intense rainfall. Heavy rainfall May 30 produced 221 ft^3/sec. The peak streamflow from snowmelt and rain in January was 179 ft^3/sec. Precipitation was 18.51 inches, about equal to the mean.

Monthly runoff, Table 3.6, was below average during winter and early spring and above average in June, favorable for irrigation.

Reynolds Creek Tollgate: Runoff from this 13,453-acre watershed was 8.15 inches, 89 percent of the 15-year mean, Table 3.5. Peak streamflow was 163 ft^3/sec, 85 percent of the mean, April 23, and resulted from snowmelt. Precipitation was 29.08 inches, 3 percent above the mean. Monthly runoff, Table 3.6, October-March,was slightly less than average and was about normal in other months.

BOISE FRONT WATERSHEDS

Upper Maynard Gulch: Runoff from this 725-acre watershed was 6.8 inches in the 1980 water year, Table 3.7. The peak streamflow was 6.99 ft^3/sec on May 26, 1980, caused by 2.78 inches precipitation May 24-26. Water year precipitation was 25.55 inches at 3,800 feet near the runoff station, 29.82 inches at mid-watershed elevation, 4,650 feet, and 30.95 inches at 5,450 feet elevation near the headwaters.

Lower Maynard Gulch: Runoff from this 644-acre watershed 1 1/2 miles downstream from the Upper Maynard runoff station was 2.0 inches, Table 3.7. Peak streamflow was 12.43 ft^3/sec on May 26, 1980, from over 2 inches of precipitation May 24-26 and was 19.84 ft^3/sec on May 6, 1980, from 1.3 inches of intense rainfall at lower elevations. Mid-watershed precipitation was 22.93 inches and Boise precipitation was 15.65 inches, 134 percent of the 1941-80 mean.

Camp Creek and Highland Creek: These runoff stations were discontinued in 1980 and records are incomplete.

Table 3.5.--Water year precipitation, runoff, and peak streamflow for main stem watersheds.

	Reynolds Creek Outlet				Reynolds Creek at Tollgate			
Water Year	Precipitation[1/]	Runoff	Peak Streamflow	Date of Peak	Precipitation[2/]	Runoff	Peak Streamflow	Date of Peak
	inches	inches	ft^3/sec		inches	inches	ft^3/sec	
1963	25.03	1.85	2331	Jan. 31	31.07	----	----	----
1964	15.25	2.45	188	Jan. 25	24.25	----	----	----
1965	26.83	7.05	3850	Dec. 23	38.93	----	1100[3/]	----
1966	9.05	0.76	59	Apr. 1	13.79	3.55	59	Apr. 1
1967	19.68	2.19	265	June 7	28.10	9.09	288	June 7
1968	14.20	0.61	327	Feb. 21	21.51	3.08	186	Feb. 21
1969	16.85	3.60	900	Jan. 21	29.11	11.47	405	Jan. 21
1970	20.13	2.70	729	Jan. 27	31.35	9.64	240	Jan. 27
1971	24.96	4.78	540	Jan. 18	41.89	14.98	196	May 6
1972	22.13	6.07	678	Mar. 2	38.12	16.45	271	Mar. 2
1973	16.19	1.85	166	Apr. 17	25.18	6.00	147	Apr. 17
1974	17.14	4.37	291	Mar. 29	29.53	12.75	195	Mar. 29
1975	19.57	4.12	281	Mar. 25	31.18	13.31	231	June 2
1976	20.34	2.84	140	Apr. 5	29.90	10.05	130	May 10
1977	11.41	0.35	1119	June 11	15.49	1.51	17	Apr. 8
1978	19.64	3.29	589	Apr. 26	28.98	11.32	230	Apr. 26
1979	14.56	2.06	1662	Jan. 11	20.19	6.78	121	Jan. 11
1980	18.51	2.26	259	May 6	29.08	8.15	163	Apr. 23
MEAN	18.42	2.96	798		28.20	9.20	192	

1/ Raingage No. 116X91.

2/ Raingage No. 155X07.

3/ Estimated peak flow.

Table 3.6.--Water year runoff in 1980 and the mean of record by months.

Month	Reynolds Creek Outlet Runoff 1980	Reynolds Creek Outlet Runoff 1963-1980	Reynolds Creek Tollgate Runoff 1980	Reynolds Creek Tollgate Runoff 1966-1980
	inches			
October	.018	0.025	.057	0.082
November	.020	0.046	.081	0.124
December	.038	0.164	.099	0.218
January	.223	0.397	.421	0.579
February	.258	0.273	.499	0.420
March	.262	0.472	.419	1.002
April	.386	0.559	2.191	1.796
May	.557	0.629	2.691	3.217
June	.416	0.306	1.360	1.426
July	.044	0.049	.215	0.246
August	.016	0.022	.042	0.049
September	.020	0.014	.071	0.039
Total	2.258	2.956	8.146	9.208

GREEN AND AMPT INFILTRATION EQUATION PARAMETERS

Required for the application of an infiltration equation to runoff modeling is the specification of the equation parameters. Furthermore, the usefulness of an infiltration equation is dependent on being able to determine its parameters from easily obtainable soil data. The progress reported here is an extension of last year's report on the estimation of parameters in the Green and Ampt infiltration equation. Progress on applying these results to runoff prediction is reported in the next section.

In Table 3.8 are presented average Green and Ampt parameters, ϕ, ϕ_e, and ψ_f, estimated from an analysis of nearly 4,000 data sets of soil water retention data. Porosity values and the wetted front capillary pressure head values were estimated for Sandy Clay, as there were too few data sets for analysis. The conductivity K values are adapted from an unpublished compilation by Strait, Saxton, and Papendick. Work is continuing on developing the statistical properties of these parameters.

Table 3.7.--Summary of water year runoff by months from Maynard Gulch watersheds and water year precipitation at mid-watershed elevations.

Month	Upper Maynard Gulch				Lower Maynard Gulch[1/]		
	1977	1978	1979	1980	1978	1979	1980
	inches						
October	0.120	0.063	0.086	0.081	-0.058	-0.042	-0.049
November	0.135	0.118	0.116	0.143	-0.054	-0.048	-0.040
December	0.147	0.197	0.145	0.179	-0.031	-0.034	-0.004
January	0.147	0.490	0.202	0.447	0.280	0.321	0.277
February	0.112	0.685	0.595	0.706	0.487	0.272	0.379
March	0.111	1.314	0.912	1.421	0.379	0.070	0.443
April	0.088	1.441	0.457	1.361	0.172	-0.077	0.280
May	0.096	0.822	0.401	1.475	-0.064	-0.135	0.473
June	0.048	0.162	0.063	0.874	-0.089	-0.041	0.314
July	0.003	0.049	0.003	0.079	-0.040	-0.003	-0.039
August	0.004	0.010	0.013	0.010	-0.011	-0.015	-0.011
September	0.013	0.042	0.019	0.033	-0.150	-0.021	-0.019
	1.024	5.393	3.012	6.809	0.956	0.247	2.004
Water Year Precipitation	16.07	28.46	18.08	29.82	21.18	12.24	22.93

[1/] Minus values show streamflow losses in the channel between runoff measuring stations on Maynard Gulch about 1 1/2 miles apart.

Table 3.8.--Green and Ampt infiltration equation parameters - mean values for each soil texture class.

SOIL TEXTURE	NO.	TOTAL POROSITY ϕ	EFFECTIVE POROSITY ϕ_e	WETTED FRONT CAPILLARY PRESSURE ψ_f	CONDUCTIVITY K
				cm	cm/hr
Sand	618	0.438	0.419	8.05	11.78
Loamy Sand	278	0.434	0.401	9.93	2.99
Sandy Loam	567	0.446	0.412	16.59	1.09
Loam	285	0.464	0.444	18.91	0.340
Silt Loam	868	0.498	0.484	35.39	0.648
Sandy Clay Loam	317	0.397	0.336	27.47	0.153
Clay Loam	282	0.467	0.421	23.36	0.097
Silty Clay Loam	463	0.473	0.454	28.98	0.097
Sandy Clay	---	0.40*	0.34*	27.0*	0.051
Silty Clay	79	0.477	0.473	26.20	0.051
Clay	180	0.475	0.439	26.42	0.034

*Estimated.

AN INFILTRATION APPROACH TO RUNOFF PREDICTION

Introduction: Utilizing an infiltration equation in runoff prediction requires significantly more information and complexity as compared with the widely used SCS runoff equation procedure. Required inputs are a rainfall intensity record, antecedent soil water status, and the infiltration equation parameters. Table 3.9 compares the infiltration and the SCS runoff equation approach. While there is more objectivity with the infiltration approach, there is obviously more complexity. However, the increasing availability of soil data will make the infiltration approach feasible.

The infiltration based runoff prediction approach reported here uses a 24-hour rainfall distribution and total, for example, an SCS Type II, 24-hour distribution. A revision of SCS rainfall distribution graphs is now in progress; however, the mechanics of the described procedure are still applicable. Table 3.10 gives the accumulated total rainfall and the intensity values in 1-hour increments for the Type II, 24-hour rainfall distribution. Both ordinates are given as a ratio to the 24-hour total.

Table 3.9.--Comparison of runoff prediction approaches.

	APPROACH	
Factors	SCS Curve Number[1/]	Infiltration[2/]
Precipitation:	Rainfall amount and duration	Rainfall histograms or rainfall distribution with amount and duration
Soil:	Antecedent Soil Moisture (I, II, or III)	Antecedent soil water storage (volume) by soil layers or depth
	Hydrologic Soil Group (HSG)	Soil water properties by layers or depth - bulk density, saturated conductivity, and water entry value or bubbling pressure
	Initial Abstraction (I_a), assumed as 0.2 (S)	Calculated infiltration prior to surface ponding
Cover:	Land use Treatment or Practice Hydrologic condition	Tillage influences on soil properties
		Land use and treatment practice & compaction/ crusting influences on surface soil properties
		Ground cover (live or mulch) & crusting/compaction influences on surface soil properties
Surface Storage:	Included with initial abstraction, I_a	Measured or calculated surface storage - influenced by surface topography, land use, and tillage
Surface Interception:	Included with initial abstraction, I_a	Measured or calculated interception volume by ground cover (live or mulch)

[1/] The factors under the Curve Number Approach are taken from Table 9.1 and Figure 10.1, SCS National Engineering Handbook, Section 4 - Hydrology.

[2/] The factors, Soil and Cover, under the Infiltration Approach would define the Green - Ampt infiltration parameters. The derived infiltration equation would be superimposed on the rainfall histogram (corrected for surface interception) giving rainfall excess. Deducting surface storage from rainfall excess, then, gives direct surface runoff. Under range conditions the Soil and Cover factors would represent a range site.

Table 3.10--Type II Rainfall, 24-hour duration.

TIME	ACCUMULATED RAIN P/P_{24}	INTENSITY p/P_{24}
HOURS	—	hr^{-1}
0	0	0
.5	.0053	.0108
1.5	.0164	.0115
2.5	.0284	.0124
3.5	.0414	.0136
4.5	.0555	.0149
5.5	.0712	.0165
6.5	.0887	.0187
7.5	.1089	.0219
8.5	.1328	.0264
9.5	.1625	.0341
10.5	.2042	.0543
11.5	.2833	.4281
12.5	.7351	.1092
13.5	.7989	.0473
14.5	.8380	.0344
15.5	.8676	.0263
16.5	.8914	.0218
17.5	.9115	.0187
18.5	.9291	.0165
19.5	.9446	.0148
20.5	.9588	.0134
21.5	.9717	.0124
22.5	.9836	.0115
23.5	.9947	.0108
24.0	1.0000	0

Runoff computation by the infiltration approach involves two stages, i.e., pre-ponding and post-ponding. Prior to surface ponding, the infiltration rate is the rainfall rate and, thus, no potential runoff is produced. After ponding the infiltration rate is determined by the soil properties and runoff may occur. To preserve the continuity of the time scale commencing at the start of rainfall, a correction must be made to compensate for infiltration at a rate less than the soil capacity rate during the pre-ponding. This will be illustrated in an example. Output of the infiltration based runoff procedure is the volume and duration of surface runoff supply (rainfall excess). These would be input to calculating the runoff hydrograph or the peak rate of runoff.

TIME OF PONDING

Prior to surface ponding the infiltration rate at a particular time is equal to the rainfall rate. The amount of infiltration up to that same time (less interception) is the accumulated rainfall amount. At surface ponding the Green and Ampt rate equation is

$$p = K(1 + \frac{n\psi_f}{P}) \qquad [1]$$

where p is the rainfall rate and P is the accumulated rainfall amount. The parameters are; K, the conductivity, ψ_f, the wetting front suction pressure head, and n, the available soil porosity. The product term ($n\psi_f$) is defined as Ω and is read from Figure 3.6 as a function of antecedent soil water and soil texture. Values of K as a function of soil texture are given in Table 3.11.

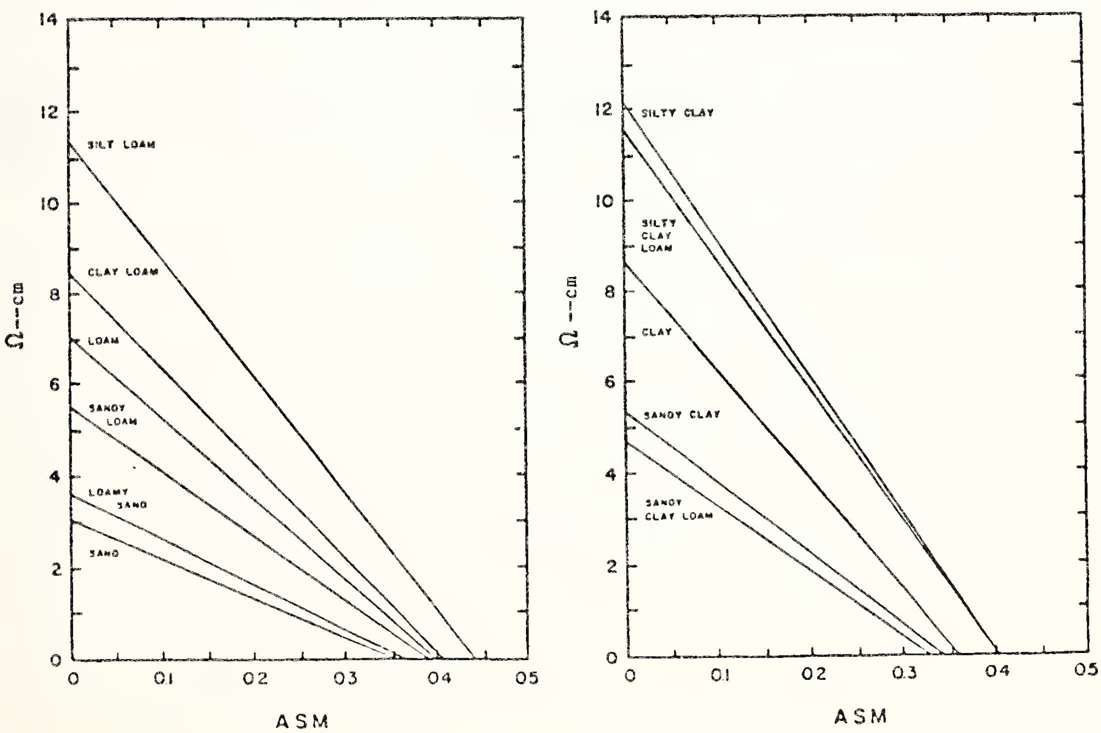

Figure 3.6.--Relationships between the Green and Ampt parameter, Ω, and antecedent soil moisture, ASM.

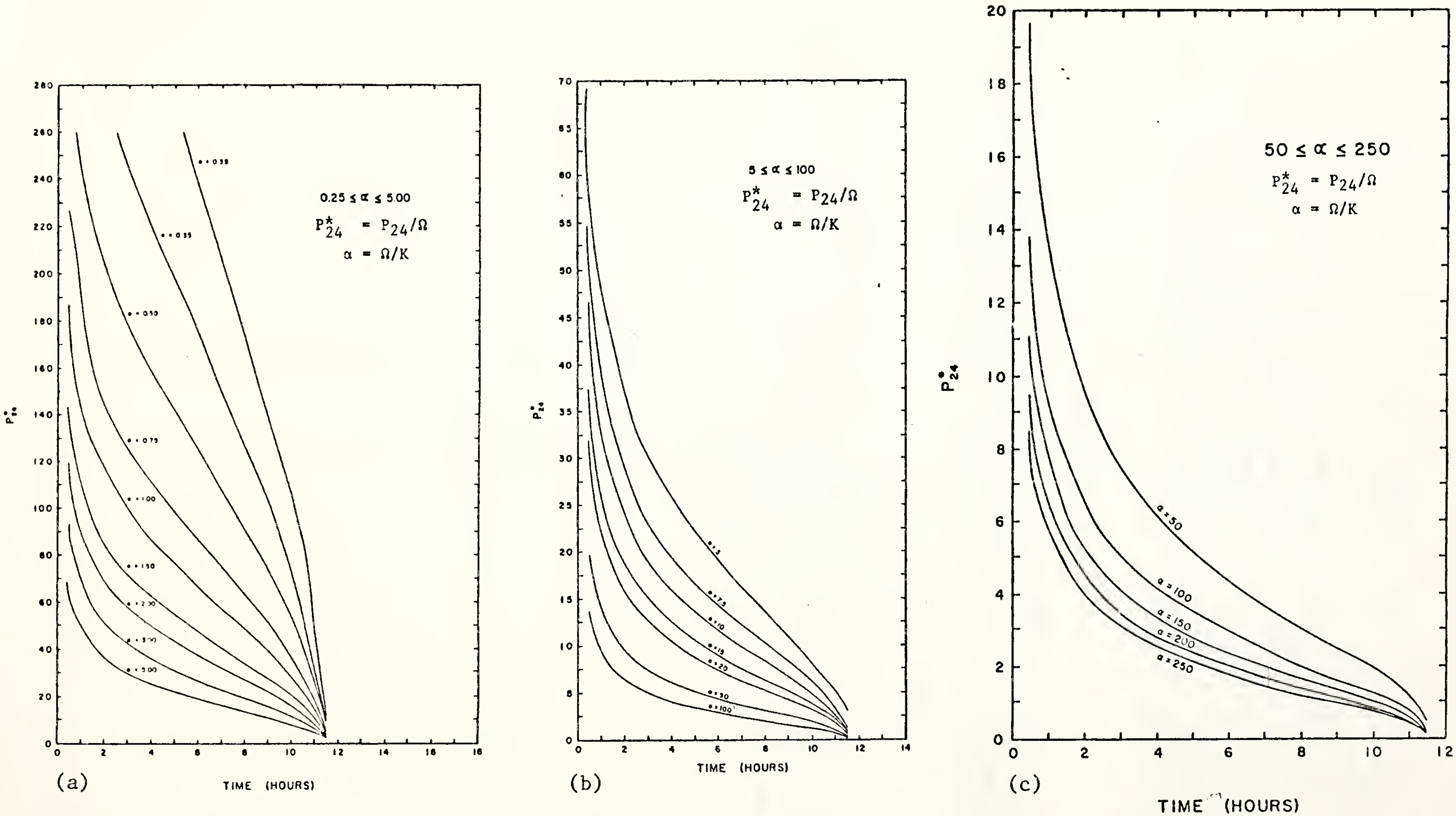

Figure 3.7.--Time to ponding related to P^*_{24} and α.

Table 3.11.--Green and Ampt Conductivity Parameter, K.

Soil Texture	K
	cm/hour
Sand	11.78
Loamy Sand	2.99
Sandy Loam	1.09
Loam	.340
Silt Loam	.648
Sandy Clay Loam	.153
Clay Loam	.097
Silty Clay Loam	.097
Sandy Clay	.064
Silty Clay	.051
Clay	.034

A relationship has been developed between the time of ponding and the 24-hour rainfall total. P_{24}^* is defined as P_{24}/Ω. The parameter, α, associated with each curve, is defined as Ω/K. Linear interpolation is assumed to be accurate between curves.

The application of Figures 3.6 and 3.7(a,b, and c) to estimate the time of ponding proceeds as follows for a Type II, 24-hour rainfall event:

1. Given the soil texture and antecedent soil water value, determine Ω from Figure 3.6 and K from Table 3.11, and calculate $\alpha = \Omega/K$.

2. From the given 24-hour rainfall amount, calculate P_{24}^* as P_{24}/Ω.

3. From Figure 3.7, for P_{24}^* and α, read the time value, t. This is the time of surface ponding, t_p.

4. The infiltration amount at ponding, Fp, is calculated as $Fp = P_{24} X (P/P_{24})$, where (P/P_{24}) is read from Table 3.10 at the time corresponding to t_p. Interpolations may be necessary.

INFILTRATION AFTER PONDING

<u>Time correction</u>: After surface ponding, infiltration occurs at the soil capacity rate. The integrated form of the Green and Ampt equation, thus, applies:

$$F - \Omega \ln\left(1 + \frac{F}{\Omega}\right) = Kt \qquad [2]$$

where

F = infiltration amount

t = time

Ω and K = parameters defined for equation [1]

Time in [2], however, can not be taken as clock time from the start of rainfall since infiltration prior to ponding was not occurring at a capacity rate. A time correction can, however, be calculated, which permits the time to be referenced to the start of rainfall. This correction is calculated as follows: Infiltration amount, F_p, at ponding would be substituted into [2] and the time calculated. This time, t_{pe}, is the equivalent time required for the total infiltration prior to ponding to have occurred under continuous ponding. The correction, t_c, to the clock time would be:

$$t_c = t_p - t_{pe}$$

where

t_p = ponding time from Figure 3.7.

Corrected clock time is

$$t_{cor} = t - t_c \qquad [3]$$

where t = actual time from the start of rainfall

Calculation of t_{pe} is facilitated by an approximation of [2] developed by Li, et al. (1976)[1/],

$$t_{pe} = \frac{F_p^2}{K(2\Omega + F_p} \qquad [4]$$

<u>Infiltration duration after ponding</u>: The infiltration rate after ponding will proceed at its capacity rate until the rainfall rate falls below the soils' infiltration rate. At that time additional surface runoff supply or rainfall excess will not be produced.

1/ Li, et al. 1976. Solutions to Green-Ampt Infiltration Equation, ASCE, J. Irrig. and Drain., Vol. 102, No. IR2. p. 239-248.

An explicit relationship is not available for calculating the end of rain excess; however, a simple "trial and error" procedure is outlined below:

1. Select a time, t_1, beyond the maximum rainfall rate, i.e., $t \geq 12$ hours.

2. Transform t to corrected time, i.e., $t_{cor} = t - t_c$

3. Calculate $t^*_{cor} = t_{cor}/\alpha$

4. Calculate $F^* = \frac{1}{2}[t^*_{cor} + \sqrt{t^*_{cor} (8 + t^*_{cor})}]$ [5][1/]

5. Calculate $f^* = 1 + 1/F^*$ [6][1/]

6. Calculate $f/P_{24} = (K/P_{24})f^*$

7. Refer to Table 3.10, determine the time value, t_2, corresponding to $p/P_{24} = (f/P_{24})$ on the falling (decreasing) segment of the Type II, 24-hour rainfall distribution.

8. If $t_2 = t_1$ or is within an allowable increment of t_1, then rain excess or direct runoff supply ends at $t_e = t_2$. Otherwise, return to step 1 with $t_1 = t_2$.

Total infiltration: The total storm infiltration can be calculated as follows:

1. $t_{cor} = t_e - (t_p - t_{pe}) = t_e - t_c$

2. $t^*_{cor} = t_{cor}/\alpha$

3. $F^* = \frac{1}{2}[t^*_{cor} + \sqrt{t^*_{cor} (8 + t^*_{cor})}]$

4. $F = \Omega F^*$

This total infiltration, up to the time t_e, includes infiltration prior to ponding, Fp, as well as rainfall excess required to fill depressional storage.

DIRECT RUNOFF AND DURATION

From Table 3.10 the total rainfall contributing to rainfall excess is the difference between the rainfall amount at the time of ponding, t_p, and the amount at the end of rainfall excess, t_e. The difference

[1/] Li, et al. 1976. Solutions to Green-Ampt Infiltration Equation, ASCE, J. Irrig. and Drain., Vol. 102, No. IR2. p. 239-248.

between total infiltrations at the end of rainfall excess and infiltration prior to ponding is the infiltration during the duration of rainfall excess. The difference between the former and the latter quantities is total rainfall excess. Subtracting depression storage from this difference then gives the total supply to surface runoff. The duration of supply to direct runoff is the difference between the time of end of rainfall excess, and the time of ponding, reduced by the time required to fill surface storage.

An example is given to illustrate these procedures:

GIVEN: Loam Soil, Antecedent Soil Moisture, ASM = 0.27 and P_{24} = 20 cm

From Table 3.11, K = 0.34 cm/hr and from Figure 3.6, Ω = 2.3 cm

CALCULATIONS:

(1) Time of Ponding: $\alpha = \Omega/K = 6.7467$

$P^*_{24} = P_{24}/\Omega = 8.6957$

From Figure 3.7b, T_p = 9 hours

From Table 3.10, P/P_{24} (at 9 hours) = 0.1477

and F_p = 2.95 cm (0.1477 X 20)

(2) Time Correction: Substituting the above values into equation [4] gives:

$$t_{pe} = \frac{(2.95)^2}{0.34\ (4.6 + 2.95)} = 3.39 \text{ hours}$$

$$t_c = 9.0 - 3.39 = 5.61 \text{ hr (time correction)}$$

$$t_{cor} = (t - 5.61) \text{ (corrected time)}$$

(3) Infiltration Duration after Ponding:

(a) t_1 = 12.0 hr $\qquad t_2$ = 15.61 hr (Table 3.10)

t_{cor} = 6.39 $\qquad t_1 \neq t_2$

t^*_{cor} = 0.9446

F^* = 1.9257 (Eq. [5])

f^* = 1.5193 (Eq. [6])

f = 0.5166

$p/P_{24} = f/P_{24}$ = 0.0258

(b) $t_1 = 15.61$ hr

$t^*_{cor} = 1.4784$

$F^* = 2.6109$

$f^* = 1.3830$

$p/P_{24} = 0.0235$

$t_2 = 16.12$ hr

$t_2 \neq t_1$

(c) $t_1 = 16.12$ hr

$t^*_{cor} = 1.5537$

$F^* = 2.7032$

$f^* = 1.3699$

$p/P_{24} = 0.0233$

$t_2 = 16.17$ hr

$t_2 \neq t_1$

(d) $t_1 = 16.17$ hr

$t^*_{cor} = 1.5606$

$F^* = 2.7116$

$f^* = 1.3688$

$p/P_{24} = 0.0233$

$t_2 = 16.17$ hr

$t_2 = t_1$

The infiltration rate equals the rainfall rate at time 16.17 hours. Rainfall excess (supply to direct surface runoff) ceases at this time.

(4) Total Infiltration:

$t^*_{cor} = 1.5606$ (From step 3)

$F^* = 2.7116$ (From step 3)

$F = F^* \times \Omega = 6.24$ cm

(5) Storm Surface Runoff:

Post-ponding rainfall = 17.67[1/] - 2.95 = 14.72 cm

Post-ponding infiltration = 6.24 - 2.95 = 3.29 cm

Total rainfall excess = 14.72 - 3.29 = 11.43 cm

[1/] From Table 3.10 the total percent of rainfall at 16.17 hours is, by interpolation, $P/P_{24} = [(0.8914 - 0.8676) \times (16.17 - 15.5)] + 0.8676 = 0.8835$. Total rainfall is 0.8835 X 20 = 17.67.

Assumed depression storage = .43 cm

[1]Supply to direct runoff = 11.43 - 0.43 = 11.0 cm

[2]Duration of direct runoff = 16.17 - 9.00 - 0.67 = 6.50 hrs

RUNOFF

<u>Groundwater investigations in semiarid environments</u>: Groundwater resources are being evaluated to determine the potential for livestock and wildlife use in semiarid environments. Development of these upland resources can also aid in reduction of livestock activity in the riparian zones, ultimately improving water quality and overall range conditions.

Before development of the groundwater resource, several characteristics of the groundwater system should be evaluated in order to determine long term storage and future supplies. These should include natural recharge potential, quality, aquifer flow capabilities, precipitation characteristics, storage potential, etc. Investigations this year concentrated on the characteristics of natural recharge.

Recharge characteristics were evaluated, using lengthy records of precipitation, soil depth, soil water, and groundwater observations. Recharge was found to occur via three mechanisms--1) infiltration through low relief, rubbly basalt outcrops; 2) infiltration through shallow soils; and 3) by transmission through bedrock channels during runoff and channel flow. Sub-basins of the Reynolds Creek Watershed are identified as examples where these mechanisms occur. Recharge is usually initiated by rainfall in excess of 20 to 30 mm over 24 hours, or higher intensity cloudburst storms.

The time it takes for a groundwater hydrograph to peak following a significant precipitation event was found to be independent of season, depending only on soil depth. Regression analysis of this relationship produced a correlation coefficient of 0.941 (see Figure 3.8).

The rate of groundwater recharge for the study area was computed at about 4.6×10^{-4} cm/min.

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[1]Supply to runoff is total rainfall excess minus depression storage.

[2]Duration of supply to direct runoff is end of rainfall excess (16.17 hrs) minus ponding time (9.00 hrs) minus time to fill depression storage (0.67 hr).

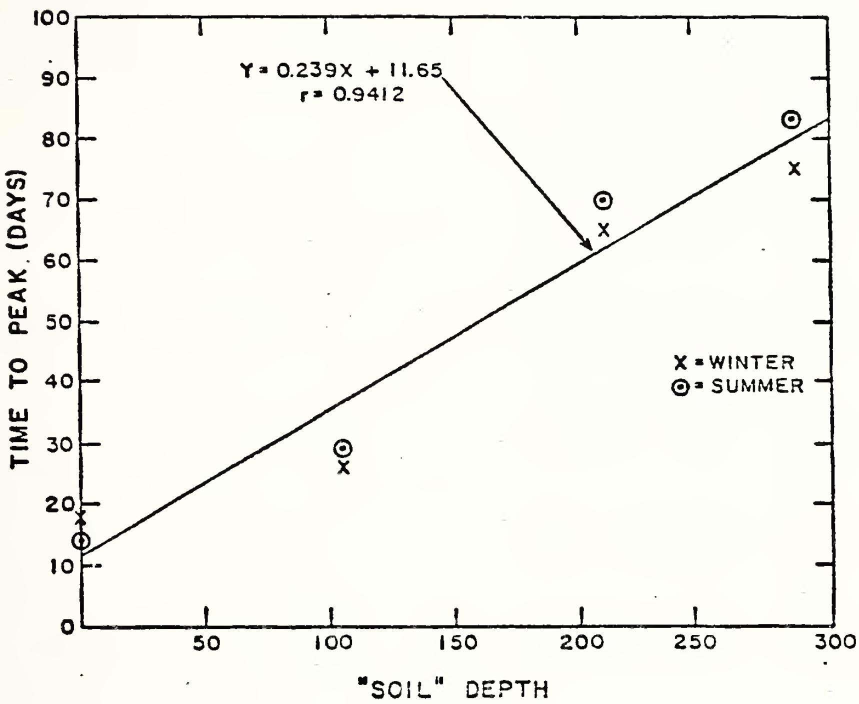

Figure 3.8.--Relationship between time to peak and soil depth.

4. EROSION AND SEDIMENT

Personnel Involved

C. W. Johnson, Research Hydraulic Engineer	Plan programs and procedures; design and construct facilities for sediment studies; perform analyses and summarize results.
G. R. Stephenson, Geologist	Determine geologic and geomorphic parameters related to sediment yield.
C. L. Hanson, Agricultural Engineer	Test various components in sediment models most applicable to rangelands.
R. L. Engleman, Mathematician	Perform data compilation and assist in analyses.
J. P. Smith, Hydrologist	Data collection, compilation, and analyses.
J. H. Harris, Scientific Aid (U. of Idaho Cooperator)	Data collection and sediment analyses.
M. D. Burgess, Electronic Technician	Designs, constructs, and services electronic sensors and radio telemetry systems.

Reynolds Creek (Reynolds Creek Experimental Watershed station locations are shown in the Introduction, Figure 1).

MICROWATERSHEDS

Flats: Sediment sampling in 1980 was inadequate for accurate computation of sediment yield, because of freezing problems, equipment failures, and mixing of sediment from different events. Total sediment was estimated at 30 pounds, as indicated by sediment tank accumulations and runoff measurements.

Nancy Gulch: Total sediment yield was estimated at less than 50 pounds in 1980, as indicated by sediment tank accumulations and runoff. This station was equipped with an automatic pumping sampler, heated enclosure, and other improvements in September - November 1980.

SOURCE WATERSHED

Reynolds Mountain East: Total sediment yield from this 100-acre watershed in 1980 was 12.7 tons, 96 percent of the 13-year mean, Table 4.1. The maximum suspended sediment concentration was about 380 mg/l.

TRIBUTARY WATERSHED

Macks Creek: Suspended sediment yield from this 7,846-acre watershed was 87 tons, only about 4 percent of the 13-year mean, Table 4.1. Over 60 percent of the yearly sediment yield was in January-February, associated with peak streamflow from snowmelt and rain on frozen soil.

MAIN STEM WATERSHEDS

Reynolds Creek at Outlet: Suspended sediment yield from this 57,754-acre watershed was 4,237 tons in 1980, 32 percent of the 14-year mean, Table 4.1. Sediment yield during the January-April period of snowmelt and frozen soil runoff was about equal to May-June sediment yield from rainfall runoff. The maximum suspended sediment concentration was nearly 25,000 mg/l on May 6, with peak streamflow. The PS 69 automatic sediment sampler installed in 1979 proved very dependable with minimum maintenance.

Reynolds Creek at Tollgate: Total sediment yield from this 13,453-acre watershed was 1,778 tons, 34 percent of the 14-year mean, Table 4.1. Over 60 percent of the yearly sediment yield was during April at peak runoff and the maximum sediment concentration was about 3,000 mg/l. Bedload was about 10 percent of total sediment yield. The PS 69 automatic sediment sampler installed in 1979 operated very satisfactorily this year.

Table 4.1.--Sediment yield in tons at Reynolds Creek Watershed Stations.

Year	Reynolds Mountain East	Macks[1/] Creek	Reynolds Creek at Tollgate	Reynolds[1/] Creek at Outlet
1967	---	---	11275	13503
1968	5.5	393	1965	4334
1969	17.0	6332	12994	39336
1970	31.1	3585	7242	15369
1971	18.1	5833	9771	28641
1972	18.3	5414	8838	37396
1973	9.4	1147	1203	2415
1974	10.3	1214	2774	5762
1975	14.2	1949	7867	9860
1976	12.4	646	2546	1430
1977	1.0	7	51	3257
1978	12.1	554	2797	8256
1979	9.2	1634	1808	11674
1980	12.7	87	1778	4237
MEAN	13.2	2215	5208	13248

1/ Suspended sediment only.

Boise Front (Boise Front runoff and sediment sampling locations are shown in the Introduction, Figure 2).

Upper Maynard Gulch: Suspended sediment yield from this 725-acre watershed was 29 tons in 1980, Table 4.2. About 64 percent of the yearly sediment yield was in May and the maximum concentration was about 1,000 mg/l during peak streamflow on May 26.

Lower Maynard Gulch: Suspended sediment yield from this 1,369-acre watershed, which includes Upper Maynard Gulch, was 168 tons, Table 4.2. The maximum suspended sediment concentration was about 5,000 mg/l on May 26, with peak streamflow. About 80 percent of yearly suspended sediment yield was during May with periods of intense rainfall.

Table 4.2.--Sediment yield from Boise Front Watersheds, 1980 Water Year.

Month	Watershed	
	Upper Maynard Gulch	Lower[1/] Maynard Gulch
	tons	
October	0.03	0.03
November	0.06	0.10
December	0.07	0.15
January	0.92	3.08
February	1.88	4.71
March	3.13	10.15
April	2.46	8.05
May	18.67	135.08
June	1.89	6.80
July	0.09	0.09
August	0.01	0
September	0.04	0.01
YEAR TOTAL	29.25	168.25

[1/] Drainage area includes Upper Maynard Gulch.

WATERSHED MANAGEMENT IN ACTION ON THE BOISE FRONT

Results of this Boise Front study were presented at the 1980 ASCE Watershed Management Symposium, Boise, Idaho, July 21-23, 1980 and published in the proceedings. The study showed that measured sediment

yields from the Boise Front in 1978-1979 were only about 10 percent of yields in 1939-1940 for comparable streamflow rates and that control of range fires and reduction in livestock grazing and recreation land abuse were mainly responsible for the decrease in sediment yields. Intensive watershed management in the last 20 years has achieved notable results.

SAGEBRUSH RANGELAND COVER, SOIL LOSS, AND SEDIMENT YIELD

Continuing hydrology and sediment transport studies on the Reynolds Creek Experimental Watershed are concerned with measurement and analysis of precipitation, cover, runoff, and sediment yield under a wide range of topographic and soil conditions. Also, determining the effects of cattle grazing on vegetative cover and erosion is a major objective of the study.

MONTHLY SEDIMENT YIELD DISTRIBUTIONS

Suspended sediment data from streams within the Reynolds Creek Watershed, 1967-1980, show widely different monthly sediment yield distributions, Figure 4.1. About 67 percent of yearly sediment yield from the 100-acre Reynolds Mountain Watershed, 6700 feet mean elevation, was in May and 23 percent was in April. In contrast, the 7846-acre Macks Creek Watershed, 4800 feet mean elevation, had about 63 percent of yearly sediment yield in January and 19 percent in March. Reynolds Creek at Tollgate, elevation range 4600-7300 feet, and Reynolds Creek at Outlet, elevation range 3600-7300 feet, show distributions for larger streams. Generally, sediment yields from areas above 5500 feet elevation were predominantly associated with spring snowmelt, and from areas below 5500 feet elevation were predominantly associated with winter snowmelt and rain with frozen soil.

EFFECTIVE PRECIPITATION AND VEGETATIVE GROUND COVER

Vegetative litter and live plants in contact with the soil surface have a major influence on reducing soil erosion. On Reynolds Creek vegetative study sites, the ground cover ranged widely from year to year and from site to site; however, the relationship between average effective yearly precipitation (measured precipitation at the sites plus blown-in snow less runoff) and average yearly ungrazed vegetative ground cover, Figure 4.2, is well defined. Two Reynolds Creek sites were not included in the analysis, because unknown amounts of snow are usually blown off the study areas in winter. Elevations ranged from 3900 to 6800 feet, average yearly precipitation ranged from 9.4 to 40.0 inches, and average yearly runoff ranged from 0.1 to 20 inches at vegetation study sites.

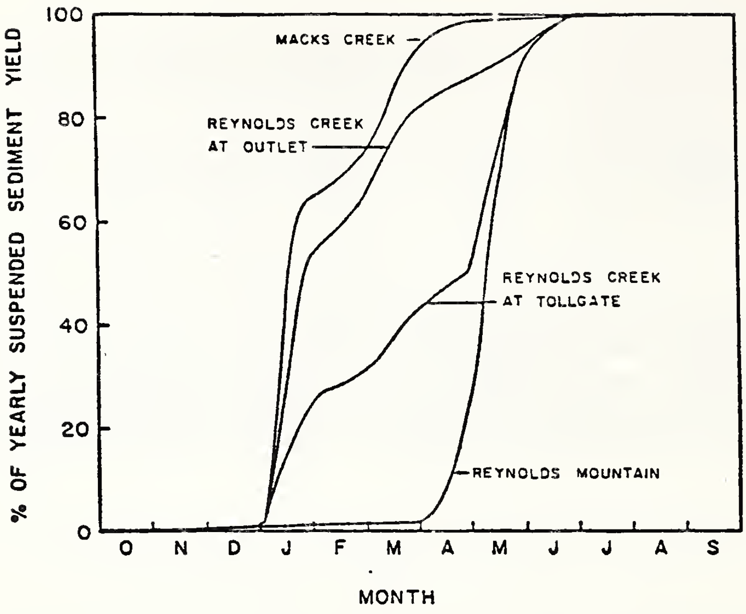

Figure 4.1.—Monthly sediment yield distributions for Reynolds Creek Watersheds, 1967-80.

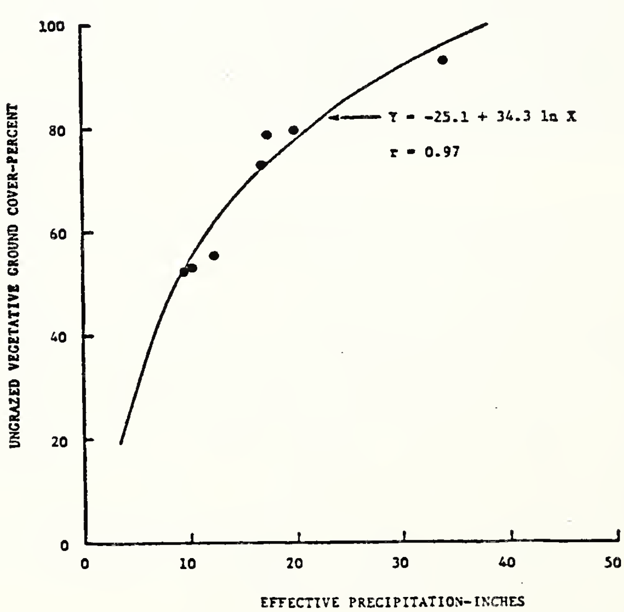

Figure 4.2.—Effective precipitation-vegetative ground cover relationship, Reynolds Creek Watershed, Ungrazed areas, 1972-80.

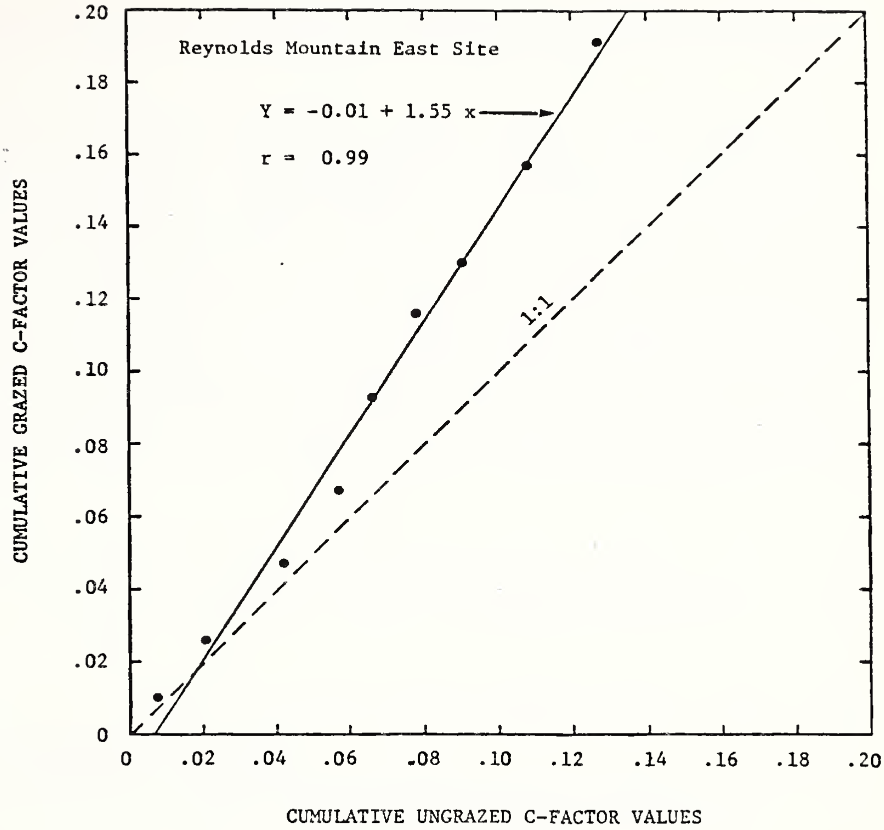

Figure 4.3.--Double-mass curve of yearly USLE C-Factor Values, 1972-80.

VEGETATIVE COVER AND POTENTIAL SOIL LOSS BY THE USLE

The Universal Soil Loss Equation, USLE,

$$A = R\ K\ L\ S\ C\ P$$

where

A = Soil loss in tons/acre/year
R = Rainfall and runoff factor
K = Soil erodibility factor
L = Slope-length factor
S = Slope-steepness factor
C = Cover and management factor
P = Support practice factor (set equal to 1.0 in this study)

was applied to sagebrush rangeland sites on the Reynolds Creek Experimental Watershed to determine potential erosion for a wide range of conditions. Average 1972-1980 estimated values of USLE factors are summarized in Table 4.3, as interpreted from Reynolds Creek hydrologic

records, soils maps, topographic maps, and vegetative cover transects. Ungrazed areas were fenced to prevent cattle grazing, 1972-1980, for comparison with adjoining grazed areas with moderate to heavy grazing.

Yearly USLE C-factor values determined from ground cover, canopy cover, and plant species data, taken by cover transects at peak standing crop, are listed in Table 4.4. Double-mass analysis was used to show the cumulative trend in difference between grazed and ungrazed values, see an example in Figure 4.3. The resulting equations and significance levels in comparing regression slope against unity for normally grazed sites are listed in Table 4.5. The only site not showing a significant difference between grazed and ungrazed areas was Whiskey Hill where the dense sagebrush did not respond to exclusion from cattle grazing. The Flats site, with least cover and precipitation, did not show a significant change for the first 5 years, then changed significantly in the remaining 4 years.

Table 4.3.--USLE Factor Values, Reynolds Creek Vegetation Study Site, 1972-80 Averages.

Site	R	K	LS	C		A, Tons/Acre/Year	
				Grazed	Ungrazed	Grazed	Ungrazed
Flats	23	0.32	0.7	0.077	0.053	0.40	0.27
Whiskey Hill	32	0.28	2.7	0.023	0.022	0.56	0.53
Nancy	25	0.28	0.9	0.048	0.033	0.30	0.21
Lower Sheep	35	0.24	3.6	0.019	0.019	0.57	0.57
Nettleton 1/	32	0.28	4.9	0.025	0.011	1.10	0.48
U. Sheep, S.F.	40 2/	0.24	7.8	0.048	0.035	3.59	2.62
U. Sheep, N.F.	65 3/	0.28	8.3	0.014	0.005	2.11	0.76
Rey. Mtn., E.	87	0.24	1.0	0.020	0.016	0.42	0.33
Rey. Mtn., W.	50 2/	0.28	0.6	0.023	0.017	0.19	0.14

1/ The grazed area at this site was severely grazed by cattle at 80-90 percent utilization.

2/ Value estimated, a major portion of precipitation is usually snow and blows off the site.

3/ Snow from adjoining areas blows onto this site.

Table 4.4.--Yearly USLE C-Factor Values at Peak Standing Crop Reynolds Creek Vegetation Study Sites

SITE AND TREATMENT	C FACTOR VALUE								
	1972	1973	1974	1975	1976	1977	1978	1979	1980
FLATS:									
Grazed	.043	.074	.047	.091	.103	.104	.122	.105	.058
Ungrazed	.043	.064	.037	.100	.130	.050	.073	.042	.017
WHISKEY HILL:									
Grazed	.011	.024	.029	.024	.020	.031	.035	.040	.020
Ungrazed	.012	.036	.024	.022	.031	.037	.022	.030	.010
NANCY:									
Grazed	.018	.070	.044	.058	.020	.046	.067	.050	.028
Ungrazed	.027	.043	.032	.040	.018	.028	.060	.044	.017
LOWER SHEEP:									
Grazed	.010	--	.023	.034	.005	.040	.023	.026	.013
Ungrazed	.011	--	.022	.027	.006	.024	.022	.033	.015
NETTLETON:									
Grazed	.017	.032	.025	.034	.018	.028	.027	.039	.025
Ungrazed	.011	.020	.012	.007	.009	.017	.008	.008	.008
UPPER SHEEP, SOUTH FACING SLOPE:									
Grazed	.020	--	.058	.054	.020	.105	.042	.069	.043
Ungrazed	.012	--	.028	.042	.032	.065	.040	.056	.030
UPPER SHEEP, NORTH FACING SLOPE:									
Grazed	.007	.016	.016	.012	.018	.018	.019	.020	.008
Ungrazed	.004	.009	.007	.005	.005	.011	.004	.003	.003
REYNOLDS MOUNTAIN, EAST:									
Grazed	.010	.016	.021	.020	.026	.023	.014	.027	.034
Ungrazed	.008	.013	.021	.015	.009	.012	.012	.018	.019
REYNOLDS MOUNTAIN, WEST:									
Grazed	.017	--	.023	.031	.006	.069	.016	.021	.012
Ungrazed	.008	--	.014	.024	.013	.064	.016	.009	.006

Table 4.5.--Regression equations and significance levels between cumulative grazed and ungrazed C-Factor values, Reynolds Creek sites, 1972-1980

Site	Regression Equation[1/]	Significance Level[2/]
Flats	$Y = -0.038 + 1.28 X$	1%[3/]
Whiskey Hill	$Y = -0.011 + 1.03 X$	N.S.
Nancy	$Y = 0.005 + 1.33 X$	.5%
Lower Sheep	$Y = 0.0004 + 1.13 X$	.5%
Upper Sheep, S. F.	$Y = 0.016 + 1.29 X$	.5%
Upper Sheep, N. F.	$Y = -0.012 + 2.69 X$	.5%
Reynolds Mtn., East	$Y = -0.010 + 1.55 X$	.5%
Reynolds Mtn., West	$Y = 0.012 + 1.14 X$	1%

1/ Y = Grazed C-Factor values, X = Ungrazed C-Factor values.

2/ Determined by tests of regression slope = 1.0.

3/ The regression slope was not significantly different from 1.0 for 1972-1976 data, but was highly significant, 0.5% level, for 1977-1980 data.

EFFECTS OF SEASONAL VEGETATIVE COVER CHANGES ON POTENTIAL SOIL LOSS

Ground cover, canopy cover, and plant species data from cover transects, run at peak standing crop and about the end of the grazing season, in 1974, 1975, 1978, and 1979, were analyzed to determine USLE C-factor changes during the grazing season, Table 4.6. The overall change in C-factors is expressed by the equation

$$Y = .0009 + .649 X$$

where

Y = C-factor values at end of grazing season

X = C-factor values at peak standing crop.

The correlation coefficient for the means, Table 4.6, is 0.90. Differences between the means of "early" and "late" C-factor values were significant at the 1 percent level using the "t" test. Data from grazed and ungrazed areas were analyzed separately to develop the following equations:

$$Y = .0056 + .4572\ X$$

where

Y = Ungrazed C-factor values at end of grazing season

X = Ungrazed C-factor values at peak standing crop.

and

$$Y = .002 + 0.749\ X$$

where

Y = Grazed C-factor values at end of grazing season

X = Grazed C-factor values at peak standing crop.

Table 4.6.—USLE C-Factor values determined from cover transects at peak standing crop and near the end of the grazing season.

SITE	USLE C-FACTOR VALUES									
	PEAK STANDING CROP					END OF GRAZING SEASON				
UNGRAZED:	1974	1975	1978	1979	MEAN	1974	1975	1978	1979	MEAN
Flats	.037	.100	.073	.042	.063	.035	.040	.026	.036	.034
Whiskey Hill	.024	.022	.022	.030	.025	.037	.009	.014	.007	.017
Nancy	.032	.040	.060	.044	.044	.038	.028	.040	.018	.031
Lower Sheep	---	.027	.022	.033	.027	---	.022	.016	.007	.015
Upper Sheep, N.F.	---	---	.004	.003	.004	---	---	.004	.003	.004
Upper Sheep, S.F.	---	---	.040	.056	.048	---	---	.033	.013	.023
Rey. Mtn., E.	.021	---	.012	.018	.017	.043	---	.008	.009	.020
Rey. Mtn., W.	.014	---	.016	.009	.013	.021	---	.008	.005	.011
GRAZED:										
Flats	.047	.091	.122	.105	.091	.038	.052	.084	.083	.064
Whiskey Hill	.029	.024	.035	.040	.032	.033	.007	.015	.014	.017
Nancy	.044	.058	.067	.050	.055	.073	.045	.060	.045	.056
Lower Sheep	---	.034	.023	.026	.028	---	.016	.014	.005	.012
Upper Sheep, N.F.	---	---	.019	.020	.020	---	---	.013	.008	.011
Upper Sheep, S.F.	---	---	.042	.069	.056	---	---	.045	.016	.031
Rey. Mtn., E.	.021	---	.014	.027	.021	.017	---	.013	.019	.016
Rey. Mtn., W.	.023	---	.016	.021	.020	.037	---	.012	.007	.019

The correlation coefficient was 0.91 for both ungrazed and grazed data. A "t" test of grazed and ungrazed means showed a significant difference at the 1 percent level.

The results of this analysis support conclusions that potential soil loss was significantly less at the end of the grazing season than at peak standing crop and that potential soil loss was significantly greater on grazed than ungrazed areas, which had been exclosed from grazing use, 1972-1980. Cover transect data, summarized in Table 4.7, show that total vegetative ground cover on ungrazed areas increased over 5 percent, grass and forb canopy cover decreased nearly 23 percent, and shrub canopy cover increased nearly 5 percent during the period from peak standing crop to near the end of the grazing season. These changes in cover result in a significant decrease in potential soil loss at nearly all sites.

These preliminary results show the need for development of a cover production-precipitation-vegetative decomposition-grazing-erosion model to further understand the complex interactions among factors contributing to erosion and sediment yield.

Table 4.7.--Percent ground cover and canopy cover from peak standing crop (early) to the end of the grazing season (late), means of 1974, 1975, 1978, and 1979 data from ungrazed areas.

Site	Total vegetative ground cover		Grass and forb canopy cover		Shrub canopy cover	
	Early	Late	Early	Late	Early	Late
Flats	46.4	60.4	22.8	3.4	6.6	12.1
Whiskey Hill	69.9	77.9	41.0	10.0	21.4	27.0
Nancy	48.4	54.9	20.0	2.0	11.5	15.0
Lower Sheep	50.5	54.1	22.5	1.3	22.0	25.0
Upper Sheep, N. F.	96.6	96.7	55.0	11.8	18.2	26.2
Upper Sheep, S. F.	33.0	33.8	17.2	5.3	22.9	26.0
Rey. Mtn., E.	76.3	76.9	38.3	12.9	25.4	29.7
Rey. Mtn. W.	36.2	44.2	19.7	7.1	11.7	16.4
Means	57.2	62.4	29.6	6.7	17.5	22.2

5. WATER QUALITY

Personnel Involved

G. R. Stephenson, Geologist	Responsible for coordinating activities with cooperators. Design collection network and responsible for project completion.
R. C. Rychert, Microbiologist Boise State University (Summer Employment)	Cooperator in microbiological aspects of rangeland streams as effected by grazing practices.
J. H. Harris, Scientific Aid (U. of Idaho Cooperator)	Responsible for collection of water samples and laboratory analyses.
S. C. Kroeger, Research Technician (U. of Idaho Cooperator)	Assists in collection of field data.
R. L. O'Brien, Hydrologic Aid	Assists in laboratory analyses and data processing.
A. P. Veigel, Biologic Technician (Boise State University Cooperator)	Assists in laboratory analyses and data processing.

WATER QUALITY OBSERVATIONS - BOISE FRONT

Water quality baseline information continues to be developed from samples collected at four sites on the Boise Front rest-rotation grazing system. The four sites are located immediately upstream from weirs, which record runoff continuously. The sites are located such that the data will reflect the grazing practices. Figure 5.1 gives the site locations and grazing activity for 1980.

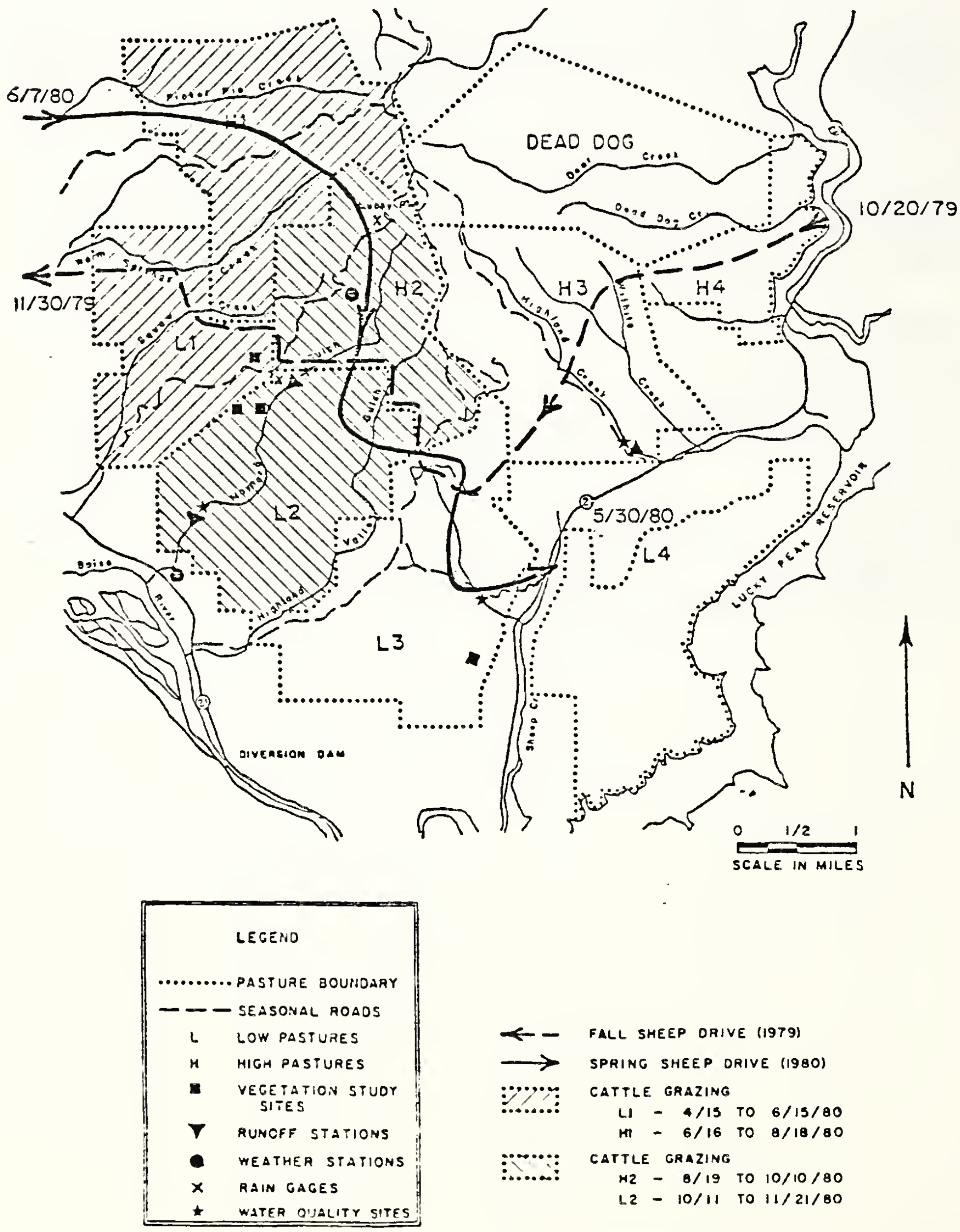

Figure 5.1.-- Boise Front site locations and grazing activity, 1980.

Table 5.1 gives the water quality data for the four sites for 1978-1980 water years. Total number of samples varies because of intermittent streamflow at several sites.

Table 5.1.--Water quality characteristics, Boise Front Watershed sampling sites, 1978-80.

Parameters	Units	No. of Samples (1980)	Maximum 1978	Maximum 1979	Maximum 1980	Minimum 1978	Minimum 1979	Minimum 1980	Average 1978	Average 1979	Average 1980
Lower Maynard											
pH	units	29	8.30	8.35	7.95	7.50	6.67	7.20	7.86	7.73	7.61
Conductivity	µmhos	30	190.00	190.00	160.00	62.00	60.00	62.00	124.64	116.47	101.00
Dissolved solids	mg/l	30	131.10	149.97	143.93	42.78	54.23	62.46	86.00	114.05	95.03
Calcium	mg/l	21	—	19.34	17.90	—	10.52	7.63	—	14.52	12.68
Magnesium	mg/l	6	—	2.95	2.70	—	2.00	1.66	—	2.35	2.14
Sodium	mg/l	19	—	15.49	10.80	—	3.00	7.30	—	7.90	8.95
Phosphorous	mg/l	17	—	0.03	0.27	—	0.03	0.03	—	0.03	0.09
Nitrate	mg/l	3	—	0.03	1.16	—	0.03	0.64	—	0.03	0.84
SiO_2	mg/l	2	—	36.00	40.00	—	21.50	27.00	—	32.78	33.50
Sodium adsorption ratio	ratio	—	—	—	—	—	—	—	—	--	--
Suspended solids	mg/l	11	41.20	167.60	124.00	2.00	3.00	3.00	12.49	21.28	33.89
Total coliform	cts/100 ml	29	2000.00	980.00	38400.00	0.00	0.00	300.00	298.19	234.00	8139.31
Fecal coliform	cts/100 ml	29	1720.00	675.00	580.00	0.00	0.00	0.00	225.56	81.52	49.07
Fecal strep	cts/100 ml	29	305.00	3320.00	3700.00	8.00	0.00	8.00	101.50	431.81	473.86
COD	mg/l	13	15.60	6.14	27.78	6.30	0.00	0.00	8.06	2.89	6.84
BOD	mg/l	6	2.00	3.40	1.90	0.00	0.00	0.00	1.32	1.05	1.75
DO	mg/l	30	10.50	10.00	10.50	7.00	5.50	7.50	8.75	8.35	9.13
Camp Creek											
pH	units	25	8.50	8.20	8.00	7.40	6.92	7.40	7.94	7.68	7.72
Conductivity	µmhos	25	190.00	105.00	165.00	90.00	100.00	85.00	130.78	101.67	116.00
Dissolved solids	mg/l	25	131.10	115.92	139.10	62.10	99.36	89.73	90.24	107.02	111.54
Calcium	mg/l	17	—	11.23	18.00	—	11.23	10.80	—	11.23	15.13
Magnesium	mg/l	3	—	2.64	3.40	—	2.64	2.42	--	2.64	2.86
Sodium	mg/l	15	—	9.76	10.90	—	9.76	7.90	—	9.76	8.94
Phosphorous	mg/l	14	—	0.03	0.23	—	0.03	0.04	—	0.03	0.10
Nitrate	mg/l	—	—	0.03	—	—	0.03	—	—	0.03	—
SiO_2	mg/l	2	—	32.00	45.00	—	32.00	27.00	—	32.00	36.00
Sodium adsorption ratio	ratio	—	—	—	—	—	—	—	—	--	—
Suspended solids	mg/l	9	—	19.00	161.50	—	3.00	3.00	—	11.50	53.46
Total Coliform	cts/100 ml	25	472.00	775.00	22000.00	0.00	12.00	20.00	165.57	139.67	4946.80
Fecal Coliform	cts/100 ml	25	280.00	528.00	270.00	0.00	0.00	0.00	38.57	110.33	45.72
Fecal strep	cts/100 ml	25	345.00	550.00	2000.00	4.00	4.00	6.00	80.21	124.33	248.08
COD	mg/l	12	9.20	—	26.11	3.70	--	0.00	6.88	—	8.78
BOD	mg/l	2	—	—	1.50	—	—	0.50	—	—	1.00
DO	mg/l	25	10.50	10.00	10.50	7.50	9.50	7.00	8.81	9.67	8.54
Upper Maynard											
pH	units	37	8.30	8.20	8.20	7.30	6.53	7.30	7.77	7.70	7.70
Conductivity	umhos	37	230.00	200.00	205.00	49.00	60.00	49.00	123.08	110.28	113.16
Dissolved solids	mg/l	37	158.70	158.63	167.81	33.81	66.65	54.43	84.93	110.77	103.25
Calcium	mg/l	30	23.45	18.61	27.90	18.24	9.10	6.47	20.84	12.57	14.61
Magnesium	mg/l	16	3.40	2.87	3.68	2.92	1.65	1.32	3.16	1.92	2.67
Sodium	mg/l	28	12.18	8.00	12.80	10.58	2.90	6.25	11.39	5.65	9.14
Phosphorous	mg/l	28	0.05	0.03	0.22	0.02	0.03	0.03	0.04	0.02	0.09
Nitrate	mg/l	2	0.06	0.02	1.41	0.04	0.02	0.66	0.05	0.02	1.03
SiO_2	mg/l	3	36.10	39.55	37.00	26.06	20.00	26.75	31.08	29.78	30.42
Sodium adsorption ratio	ratio	--	—	--	—	--	--	--	--	—	—
Suspended solids	mg/l	11	30.40	23.50	120.40	0.00	2.00	3.00	7.76	7.63	30.58
Total coliform	cts/100 ml	37	1580.00	2300.00	40000.00	40.00	0.00	100.00	433.88	382.13	9833.43
Fecal coliform	cts/100 ml	37	780.00	1322.00	3820.00	0.00	0.00	0.00	217.35	230.13	310.27
Fecal strep	cts/100 ml	37	2005.00	3220.00	9300.00	10.00	13.00	18.00	319.00	368.52	919.78
COD	mg/l	13	9.90	13.10	25.19	5.10	0.00	0.00	7.28	4.80	7.38
BOD	mg/l	7	2.50	2.50	2.50	0.50	0.00	0.00	1.50	0.55	0.96
DO	mg/l	37	11.00	10.00	10.50	8.00	7.00	5.00	8.94	8.24	8.50
Highland Valley											
pH	units	47	8.40	8.10	9.20	7.41	6.50	7.15	7.77	7.52	7.62
Conductivity	umhos	47	173.00	225.00	200.00	70.00	70.00	80.00	116.36	126.03	104.30
Dissolved solids	mg/l	47	119.37	192.51	161.46	48.30	82.11	75.62	80.29	119.38	107.30
Calcium	mg/l	39	17.43	22.37	16.50	16.63	10.79	8.20	17.03	17.43	13.30
Magnesium	mg/l	16	4.50	3.15	3.58	4.50	2.30	1.86	4.50	2.83	2.92
Sodium	mg/l	37	9.89	14.28	8.80	9.43	2.80	6.10	9.66	9.52	7.60
Phosphorous	mg/l	32	0.27	0.16	0.30	0.23	0.05	0.07	0.25	0.10	0.14
Nitrate	mg/l	3	2.00	0.24	6.33	0.62	0.24	2.82	1.31	0.24	4.37
SiO_2	mg/l	3	37.80	42.21	42.00	27.27	26.50	27.50	32.54	34.61	34.42
Sodium adsorption ratio	ratio	--	--	--	—	--	--	--	--	--	--
Suspended solids	mg/l	15	132.40	210.70	621.80	2.00	2.00	14.50	52.68	23.76	111.92
Total coliform	cts/100 ml	47	3770.00	31000.00	32000.00	0.00	0.00	100.00	648.06	3646.75	8308.72
Fecal coliform	cts/100 ml	47	2020.00	23200.00	3500.00	0.00	0.00	14.00	193.10	1295.06	240.66
Fecal strep	cts/100 ml	47	4960.00	99000.00	9300.00	8.00	0.00	12.00	811.21	5655.69	1020.47
COD	mg/l	23	29.40	39.57	92.70	7.80	2.00	0.58	15.51	9.61	14.42
BOD	mg/l	18	3.00	6.40	5.00	1.00	0.00	0.00	1.94	1.65	1.67
DO	mg/l	45	10.50	9.50	10.50	7.50	6.00	6.00	8.76	7.76	8.66

When comparing the data by site from Table 5.1 for all 3 years, bacterial variations are the most significant. Of these three variables, the fecal coliforms relate more specifically to grazing. This has been verified previously and discussed in past Interim Reports. Variations of the fecal coliform indicator between sites and within sites, for the 3-year period, reflect mainly the effects of rotational grazing. No other indicators show as consistent a relationship.

Table 5.2 gives the average fecal coliform concentration for each year for each field in the rest-rotation system. The years in which the fields were grazed generally show consistently higher concentration than the ungrazed fields. Field L2, characterized by the Lower Maynard site, was grazed during the 1980 season, but the cattle were not turned in until after September 30, the end of the water year, which is the cutoff date for this report. The channel at the sampling site had ceased flowing by mid July.

Table 5.2.--Average fecal coliform concentrations

		1978	1979	1980
Lower Maynard	(L2)	$\boxed{255}$*	82	$\boxed{49}$**
Camp Creek	(L3)	38	$\boxed{110}$	46
Upper Maynard	(H2)	$\boxed{217}$	230	$\boxed{310}$
Highland Valley	(H3)	193	$\boxed{1295}$	240

*Framed values indicated field grazed that year.

**Cattle not turned in until after October 1, 1980.

Fields H1 and L1 were scheduled for grazing in 1980, but because of inaccessibility, no streamflow measuring sites are located there, and no sampling has been done. The Upper Maynard site, located in field H2, shows elevated fecal coliform counts in 1979. These occurred mainly during January when a large herd of deer remained in the area, and during late May when the sheep herd spent several days above the site (see 1979 Interim Report for more detail).

Figure 5.2 shows graphically the variation in fecal coliform concentrations throughout the year for all four of the Boise Front sites. The only evidence of winter concentrations of deer appears above the Highland Valley site (H3) during January, February, and May; and Camp Creek

site in April. This also agrees with observations by field technicians. The fall sheep drive passed through field H3 (Highland Valley site), L3 (Camp Creek site), and L2 and H2 boundary (Lower and Upper Maynard sites) during October-November 1979. The lower Maynard and Highland Valley sites were the only ones recording fecal coliform evidence of the sheep, as Camp Creek and Upper Maynard sites had ceased flowing. The spring sheep drive for 1980 moved through the areas during May. The Lower Maynard, Upper Maynard, and Camp Creek sites (L2, H2, and L3, respectively) were the only ones affected, as seen on Figure 5.2. The Upper Maynard site, field H2, was the only site during the year recording the effects of cattle grazing. Cattle had strayed into the area through broken fences or open gates in July, and were turned into the area in mid August.

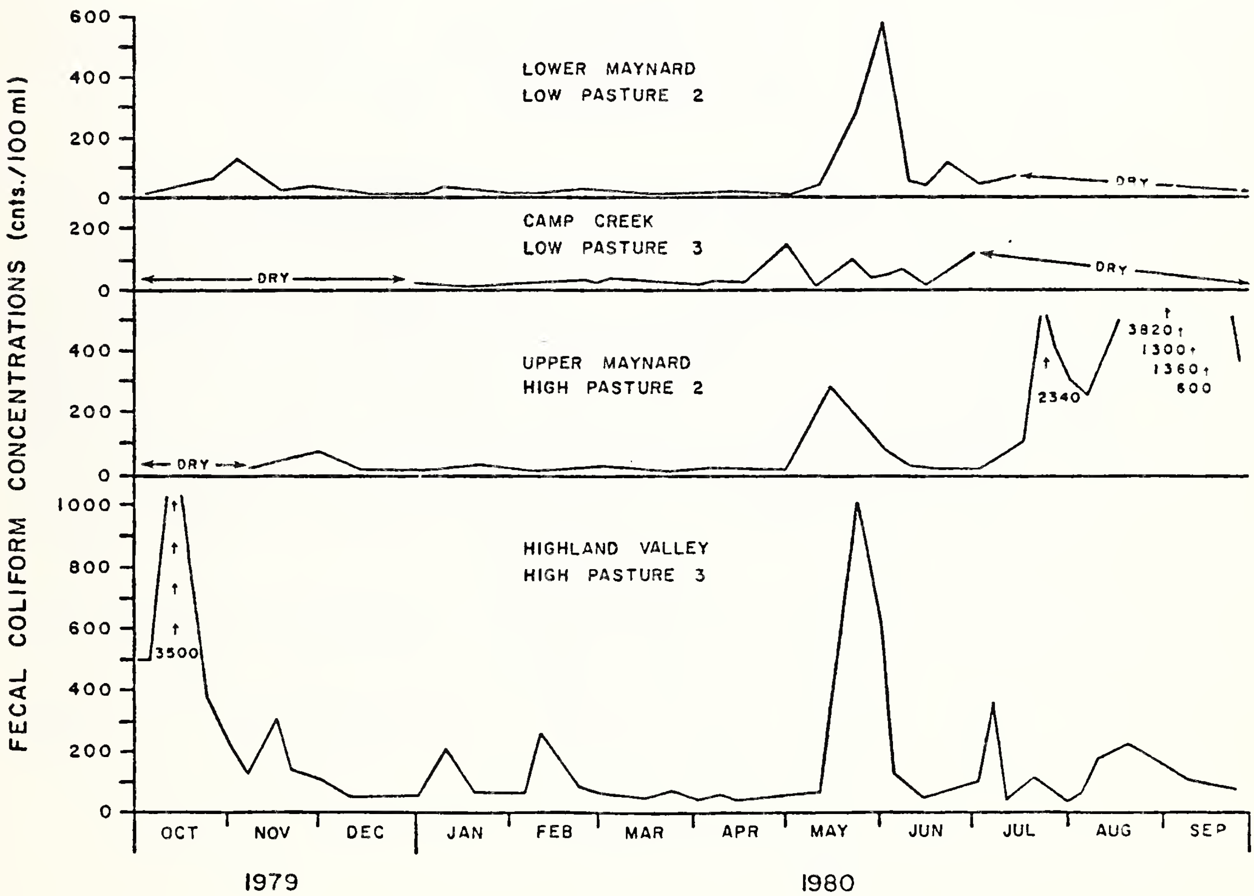

Figure 5.2.--Fecal coliform concentrations. Boise Front sampling sites.

COMPARISON OF GRAZING PRACTICES

An effort has been made to develop a method by which the effects of grazing practices on water quality can be compared. The method used for this preliminary work is given on Figure 5.3. Fecal coliform data from four different grazing practices were used, plotting the concentration on log-probability paper. Characteristics of the different practices are given on Table 5.4. Data collected and reported in past years on the Reynolds Creek Watershed were used in this analysis, along with the Boise Front data.

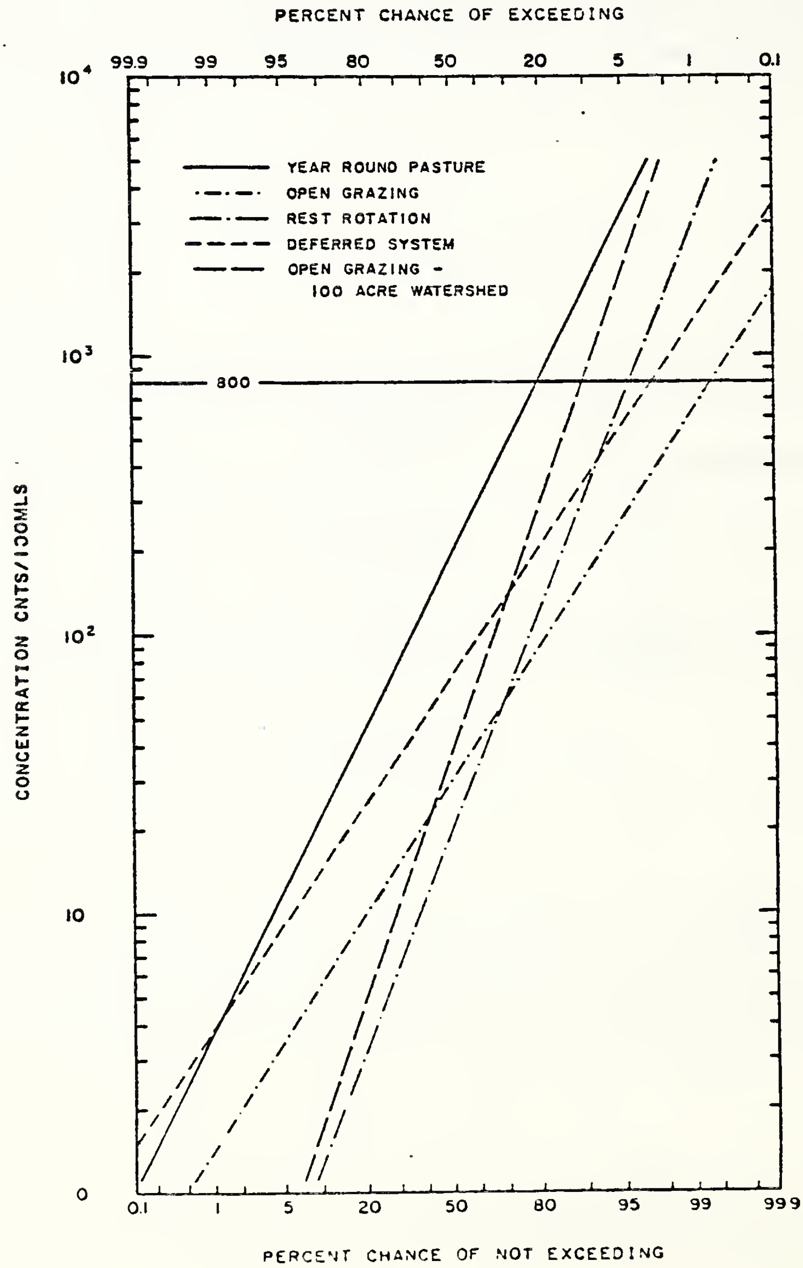

Figure 5.3.-- Comparison of grazing practices.

Table 5.4.--Grazing practice characteristics.

Grazing System	Location	Ac/AUM
Rest-Rotation	Boise Front	5
Deferred System	Reynolds Creek Watershed	6
Open System	Reynolds Creek Watershed	18
Open System (Sub-System)	Reynolds Mtn. Watershed (100 Acres)	18
Year Round Pasture	Reynolds Creek @ Snake River	5 cows/acre

The value of this method of comparison could best be used for determining which system is most likely to produce fecal coliform concentrations in exceedance of any particular level. For example, water quality standards for the streams sampled are 800 counts of fecal coliform bacteria as the upper limit. The percent chance of exceeding this limit for the sites in the different grazing systems used here are given on Table 5.5. A subunit of the open system, a 100-acre watershed that contains a perennial stream, was included. Cattle favor this area of the open system because of easy access, plush grass, good water, and shade. Because of these characteristics, frequency of contact to the stream is greater and the fecal coliform concentrations are higher.

Because of the different grazing intensities of the systems and the different physical characteristics within each area, more vigorous use of this method is not justified without additional data. However, it can be used on an annual or long-term basis to compare these particular systems in their present use. Any gross changes in AUM, vegetative cover, etc., would make further evaluation necessary.

Table 5.5.--Percent chance of exceeding 800 counts of fecal coliform bacteria in grazing system sites.

Grazing System	% Chance of Exceedance
Rest-Rotation	4.0
Deferred System	3.0
Open System	0.7
Open System (Sub-System)	15.0
Year Round Pasture	20.0

PROGRESS REPORTS

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